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Art. VI.—*The Ordovician and Silurian Rocks of the Bulla-Sunbury Area, and Discussion of the Sequence of the Melbourne Area.*

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Introduction.

The Quarter Sheets embracing portions of the Keilor, Broadmeadows, Kinlochewe, Beveridge, Bolinda Vale, and Sunbury areas, were among the first to be surveyed by the Geological Survey in the middle decades of last century. The geologists

responsible for them worked under the direction of Alfred R. C. Selwyn, who was trained in the British school; hence we find frequent allusions to British faunal assemblages. Sir Frederick McCoy who, before his arrival in Victoria, had done outstanding work on the Silurian of England and Wales, was appointed palaeontologist to the Geological Survey of Victoria in 1856, and the notes on the Quarter Sheets express, to a large extent, his considered judgment. To appreciate it, we should review the development of the Silurian and Ordovician as we now know them.

The Silurian, described by Murchison in 1839(29) was, up to 1852, assumed to include four formations, viz.:—

(4) Ludlow.
(3) Wenlock.
(2) Caradoe.
(1) Llandeilo.

In 1852 Sedgwick(33), largely on the palaeontological work of McCoy, showed that the Caradoe included two distinct faunal divisions, the upper one being intimately allied to the Wenlock, for which he proposed to revive the name of May Hill Sandstones, while the other was equivalent to part of the Bala. Aveline and Salter(11) in 1854 confirmed Sedgwick's conclusions, and Salter showed that the Upper Caradoc was an impersistent formation at the base of the Wenlock. Sedgwick placed in the Bala the Coniston grits, flags, and limestone, but the grits and flags have since been relegated to the Ludlow, and the limestone to the Upper Ordovician, so that we know now there was a hiatus between McCoy's Upper Caradoe (May Hill Sandstones) and the one bed in his Bala that is in its normal, if not in consecutive, order, viz., the Coniston Limestone. Later Aveline showed that the Pentamerus sandstones of Llandovery were stratigraphically below the Upper Caradoe of Shropshire, and, in 1867, Murchison(30) included them in the newly-created Llandovery formation. The Llandovery, as such, was unknown to McCoy when he identified the fossils from the areas represented in the Quarter Sheets. The following is the stratigraphical order (abridged) of O. T. Jones and W. W. Watts in 1929(11). We have tabulated with it Sedgwick's (incidentally McCoy's) order of 1852 in so far as it relates to the problem to be discussed.

	O. T. Jones and W. W. Watts 1929.	
Series.	Zone.	Sedgwick 1852.
9. Downtonian		
8. Ludlovian		Ludlow
7. Wenlockian	Cyrtograptus lundgreni	Wenlock
	C. rigidus	
	C. linnarssoni	
	C. symmetricus	
	Monograptus riccartonensis	
	Cyrtograptus murchisoni	

6. Llandoverian	Monograptus crenulatus	May Hill Sandstones (Upper Caradoc)
	M. griestonensis	
	M. crispus	
	M. turriculatus	
	Rastrites maximus	
	Monograptus halli	
	M. sedgwicki	
	Cephalograptus cometa	
	Monograptus convolutus	
	M. leptotheca	
	Pentamerus oblongus	
	Mesograptus magnus	
	Monograptus triangulatus	
	Sowerbyella duplicata	
	Monograptus cyphus	
	M. acinaces	
	M. atavus	
	Mesograptus modestus	
	Cephalograptus acuminatus	
	Glyptograptus persculptus	
5. Ashgillian	small Climacograptids	
	Dicellograptus anceps	Coniston Limestone (Bala)
	D. complanatus	
4. Caradocian	Pleurograptus linearis	
	Dicranograptus clingani	Bala Limestone
	C. wilsoni	
3. Llandeilian		
2. Llanvirnian		
1. Skiddavian		

In Sedgwick's order we have omitted the Coniston grits and flags, but we have endeavoured to place the other beds to which he refers in stratigraphical juxtaposition to those in Jones and Watts' order.

To McCoy's genius we must credit that happy correlation of Victorian with British faunal assemblages. The parallelism is striking, and, recognizing the limitations of homotaxis, which doubtless appealed to him, we have endeavoured, with some measure of success, to work on the same lines. This contribution is an attempt to establish the relationship of the various groups in the area specified from their positions in the field and in the light of current palaeontological evidence in Britain. The area has been re-examined, boundaries re-mapped, and many new data accumulated. It became evident that the problem had its solution in areas much further afield, and that it was necessary to review the history and premises of the subdivision of the Upper Ordovician and Silurian attempted by workers subsequent to McCoy. Thus, while it may be taken as a revision of such in the area west of Melbourne, the correlative proof of its accuracy elsewhere leads us to believe that it has a wider application in Victoria.

McCoy's pioneer efforts, the particulars of which are incorporated on the Quarter Sheets and later amplified in the Prodromus(28), constitute the only systematic work over a wide area other than that of W. J. Harris and W. Crawford(17). Their work is on the north-western portion of the area and represents systematic collecting and determinations for the purpose of elucidating the stratigraphy. It has been of considerable assistance, and Harris and Crawford have placed at our disposal their intimate knowledge of the area worked by them.

Chapman(4) has published papers on the shelly fossils and worm impressions, and made some graptolite determinations, and T. S. Hall has determined graptolites from Bulla and elsewhere.

When the necessity arises, these contributions will be reviewed in the context with more or less detail.

I. Summary of Work and Research.

The stratigraphical work of the early Geological Survey laid the foundations of all subsequent work. The work, as far as the geology is concerned, was done by Selwyn, Ulrich, and Aplin, with McCoy as Palaeontologist, and is published as Quarter Sheets 1 N.W.(37), 2 S.W.(42), 2 N.W.(1), 3 S.W.(42), 6 S.E.(2), 7 N.E.(2), and 7 S.E.(1). The surveys were commenced in 1856, all the sheets being issued together in 1863. (See Fig. 1.)

The boundary between the Upper Ordovician and Silurian (i.e., the Lower Silurian and Upper Silurian of the Survey) caused some difficulties, which they attempted to overcome by making the geological boundaries of these two systems coincide with the boundaries of the sheets. The boundaries of the Quarter Sheets are shown on Map No. 1. Attention had been given to the placing of the boundary as in one edition of Q.S. 7 S.E., the base of the Silurian is marked one-eighth of a mile from the eastern boundary of the sheet.

On Q.S. 1 N.W. several localities of graptolites and shelly fossils were determined as Silurian.* These occur in association with conglomerate bands.

On Q.S. 2 N.W. one important locality is noted (B3) with graptolites and shelly fossils. These are Silurian in age.

On Q.S. 3 S.W. two localities are to be noted (B7) on the Deep Creek, which we have not been able to find, and another near the junction of Konagaderrer and Deep Creeks where "Conglomerate and Stenopora" are noted, and the horizon was determined as "May Hill Sandstone." No trace of this conglomerate was found and, apart from worm tracks, we were unable to find fossils.

* The terms Ordovician and Silurian are used in the present paper in the present-day meaning, except where otherwise stated.


Clarkefield
Bolinda
DARRAWEIT GUIM
Konagaderra Creek
BUTTLEJORRK
Jackson's Creek
Emu Creek
Fentons
BOLINDA
MICKLEHAM
Mt Holden
Sunbury
BULLA
Wildwood
Bald Hill
HOLDEN
Diggers Rest
Bulla
NORTHERN RAILWAY
Deep Creek
KOROROIT
Sudenham
MARIBYRNONG
Q.S. No6 S.E.
Q.S. No7 N.E.
Q.S. No3 S.W.
Q.S. No2 N.W.
Q.S. No2 S.W.
Q.S. No7 S.E.
Q.S. No8 N.E.
Q.S. No1 N.W.
M.M.
Compiled from Quarter Sheets.
REFERENCE
Tertiary
BASALT.
SEDIMENTS.
Post Upper Devonian (?)
GRANITE.
Lower Silurian (KEILORIAN)
CONGLOMERATES. & SHALES.
Upper Ordovician
BOLINDIAN.
EASTONIAN.
GISBORNIAN.

Fig. 1.

On Q.S. 6 S.E., at the junction of Riddell's and Jackson's Creek, is Ba67, incorrectly marked on the Q.S. as Ba68. The age of these beds is stated to be Ordovician (Bala).

Ba64, at the mouth of Evans Gully, on Q.S. 7 N.E. is also of Ordovician age.

On Q.S. 7 S.E. are several localities, Ba61, 62, and 63, of Ordovician age. Ba60 was determined as Silurian, and this is the reason why the Silurian boundary was shifted to the west in the one edition referred to. The Silurian Conglomerate is incorrectly coloured yellow in this map. In the original draft, however, it is shown as Silurian.

The opinion of these early workers as to the stratigraphical relationship of the various series will be stated when discussing the relationship of the Ordovician and the Silurian.

T. S. Hart(18), in a contribution in 1903, mainly confined his attention to the conglomerates near Sydenham and their mode of formation. He published a map in which the conglomerates then known were marked and gave reasons in his paper for considering their origin as glacial. The boundary of the Ordovician and Silurian rocks is shown to be about the line between areas of general high dips on the north-west and the moderate low dips to the south-east.

The contribution of A. V. G. James(20) in 1920 marks an important advance in our knowledge of this area. The physiography and the igneous rocks are dealt with in detail. Fresh fossil evidence proved that the junction of the Silurian and Ordovician would have to be placed further to the west. The conglomerates are shown to be normal and bedded, and not due to glacial action as claimed by Hart. The new fossil evidence was found at the following places:—

(*a*) *Near the mouth of Column Gully.*—*Nemagraptus* (*Coenograptus*) and *Diplograptus* are recorded. We have been unable to locate these specimens, and the collections we have made do not include *Nemagraptus*. The association of forms found at this locality is a much higher one than that of the beds with *Nemagraptus* in the other portions of the area.

(*b*) *S.E. of the Organ Pipes.*—Worm casts are plentiful in this area and, being different from the *Keilorites*(67) of undoubted Silurian rocks, they were referred to as Ordovician Worm Impressions.

(*c*) *In a bed 30 yards E. of Conglomerate* (*C1*), impressions of gill plumes of *Keilorites* were found.

(*d*) and (*e*) In area to the east of the last mentioned *Monograptus* spp. and *Trachyderma* were found.

Some attention is given to the correlation of the conglomerate bands and some lateral displacement is postulated. The presence of *Monograptus* spp., of *Keilorites* (*Trachyderma*), and the abundance of worm impressions in beds beneath the conglomerate, gave some reason for considering the conglomerate marked C1 on his map as the basal beds of the Silurian. Since *Monograptus* spp. have been found beneath the conglomerate, the boundary is obviously still further to the west. The mapping around Bulla itself is unsatisfactory.

Harris and Crawford(17), in a contribution published in 1917, discuss the western part of the area under consideration, and their map extends a little further east than Sunbury. For the purpose of this paper only the portions dealing with the Upper Ordovician rocks along Jackson's Creek need be considered. A broad zoning of the Upper Ordovician rocks is given, and a series of fossiliferous grits which they called the Riddell Grits is considered to belong to the upper part of the Upper Ordovician. They suggest that a series of Upper Ordovician beds may be above the *Dicranograptus* beds, the existence of which we have been able to verify. An east-west fault, the Sunbury Fault, is shown approximately on their plan, but since no evidence of this has been obtained in the Bulla-Digger's Rest area we venture no opinion regarding it.

Although not essentially concerned with the relationship of the Silurian and Ordovician, C. M. Tattam(41), in 1923, modifies James's map near Bulla as regards the junction of these series. He attempts to correlate the westernmost conglomerate on Jackson's Creek with that near Bulla, on the relationship and thickness of some sandstone and quartzite bands to the conglomerate. Theoretically there is no justification for this correlation, inasmuch as in a series of interbedded conglomerates, sandstones, quartzites, and mudstones, which vary when traced along their strike, it is extremely doubtful whether individual bands of isolated outcrops can be correlated on thickness and general similarity.

The north-western portion is mentioned by D. E. Thomas(45) in discussing the relationship of the Kerrie Series, and Ba67 is shown to rest on the flanks of the Mount William anticlinorium.

II. General Statement of Physiography of the Keilor-Sunbury Area.

The area examined comprises portions of the Keilor, Broadmeadows, Kinlochewe, Beveridge, Bolinda Vale, Sunbury, and Clarkefield districts within the basins of Deep, Emu, and Jackson's Creeks. It consists mainly of basalt plains into which the streams have deeply entrenched themselves. The Ordovician and Silurian rocks are exposed along the floor and the sides of

these valleys, or in low hills above the general level of the plains, areas that once formed the watersheds of the pre-basaltic streams, i.e., between Sunbury and Clarkefield and on the eastern side of the Maribyrnong River or Deep Creek. The monotony of the basalt plains is broken by a few unimportant volcanic eminences and the tree-covered hills of granitic rock occurring near Bulla and Broadmeadows. These intrusions are later than the Silurian rocks which they metamorphose; fortunately, the belt of intense metamorphism does not reach to the junction of the Silurian and Ordovician.

III. Lithology and Extent of Upper Ordovician.

The Upper Ordovician rocks consist of variously coloured shales, mudstones, and sandstones, generally thin-bedded. At certain horizons, however, massive sandstones and grits are encountered. In these areas the phenomena associated with the folding together of hard and soft bands tend to mask the relationship of the beds.

IV. Details of Sections along Creeks.

(*A*) *Jackson's Creek Sections.*

(*a*) Area between Ba67 and a point just south of Clarkefield.

For some distance the creek flows in a deep gorge with basalt extending along the valley floor. Ba67, at the junction of Riddell's and Jackson's Creeks, is very important. Fossils are so abundant and so well preserved in the soft shales that there is no difficulty in obtaining a good collection. The following is a list of fossils obtained from the main body of the exposure:—

Diplog. (Glyptog.) teretiusculus (Hisinger).
Diplog. (Glyptog.) teretiusculus var. euglyphus Lap.
Climacog. riddellensis Harris.
C. antiquus var. simulans (MS.).
Cryptograptus tricornis Carr.
Glossograptus hincksii Hopk.
Retiograptus speciosus Harris.
Tetragraptus clarkefieldi (MS.).

Under 100 feet stratigraphically above the main outcrop, in light-coloured fine soft mudstones, many of the species common to the lower bed have been found, but in addition *Dicellograptus sextans* and *Dicranograptus brevicaulis*. This bed marks the incoming of the Dicranograptidae, a fact that is corroborated by similar faunas from other parts of Victoria.

Downstream basalt reaches river level. After passing some falls Jackson's Creek is joined by another creek from the south side; here thin blue mudstones are interbedded with sandstone

and grits. The mudstones are rubbly, but yield the following forms (Loc. 23) :—

Dicranograptus ramosus var. spinifer Lapw.
D. nicholsoni Hopk.
D. cf. zic zac Lapw.
Dicellograptus spp.
Diplograptus (Orthograptus) calcaratus var. vulgatus Lapw.
D. spp.
Climacograptus bicornis (Hall, J.).
Cl. spp.

Further downstream the valley widens and exposures are more common. Grits, sandstones, shales, and mudstones occur, and, in the black beds, graptolites may be found. No exhaustive collections were made, and no distinctive feature can be given :—

Diplograptus spp.
Dicellograptus spp.
Dicranograptus spp.
Leptograptus (?) sp. nov.
Climacograptus spp.

were obtained at Loc. 24, but generally not sufficiently well preserved for detailed examination. A persistent easterly dip appears to indicate that the structure of this area is simple; this is not so, and there is ample evidence of strike faulting, the effect of which has to be taken into account.

(*b*) Area between Sunbury and Clarkefield.

In the area between Sunbury and Clarkefield, an extensive area of Upper Ordovician sediments is exposed along Jackson's Creek and in the small gullies and hills to the west. Comprehensive collections have been made where the fossils are well shown, particularly along Evans' Creek, but at many places we have sought only critical forms to fix the horizon. The area is closely and sharply folded, and here again is evidence of faulting, but, by being able to recognize a repetition of the beds, we have obtained an idea of the structure.

At the western end of Evans' Creek grit beds outcrop. To the east of this is Loc. 26, from which the following forms were obtained :—

Nemagraptus gracilis (Hall).
Climacograptus bicornis (Hall).
C. antiquus Lapw.
C. sp.
Diplograptus spp.
Glossograptus sp.
Dicellograptus divaricatus Hall.
D. sextans Hall.

Succeeding these is Loc. 29, in which have been found:—

Nemagraptus gracilis (Hall) (one spec.).
Diplograptus (Orthograptus) calcaratus var. vulgatus Lapw.
D. (Orthograptus) calcaratus var. acutus Lap.
D. (Mesograptus) multidens E. and W.
Climacograptus bicornis (Hall).
C. bicornis var. peltifer Lapw.
C. antiquus Lapw.
C. sp.
Dicranograptus nicholsoni Hopk.
D. brevicaulis E. and W.
D. ramosus var. spinifer Lapw.
Dicellograptus divaricatus Hall.
D. divaricatus var. rigidus Lapw.
D. divaricatus var. salopiensis E. and W.
D. sp.
Leptograptus cf. validus Lapw.
L. sp.

There is little doubt that this is the horizon of *Diplograptus* (*Mesograptus*) *multidens* of the British succession(9). To the east, near the mouth of Evans' Creek and a few hundred feet stratigraphically higher, is the bed representing the Ba64 locality of the Geological Survey. It is thrice repeated; on both limbs of a fold and again, still lower, in the creek. Dipping in the same direction are beds of grits, brown shales, and thin blue bands (Loc. 30). The following forms were obtained:—

Diplograptus spp.
Climacograptus bicornis (Hall).
C. spp.
Cryptograptus tricornia (Carr).
Glossograptus hincksii (Hopk.)
G. cf. acanthus E. and W.
G. hincksii.

This assemblage is interesting in that it has not been recorded from horizons higher than that of Ba67; *G. acanthus* is an Upper Darriwil form, and has not been recorded from Ba67, although Keble and Benson(25) have recorded it from a somewhat similar horizon in New Zealand. On the evidence it is lower than the horizon of Ba64 and slightly higher than that of Ba67.

The beds between it and the head of Evans' Creek are thus folded into a synclinal in the Clarkefield synclinorium. From the grits Chapman(8) has identified the following forms:—

Crinoid stems.
cf. Caryocrinus.
Keilorites cf. crassituba (Chapman).
Chonetes melbournensis, Chapman.
Camarotoechia decemplicata, Sowerby.

Trematospira liopleura, McCoy.
Rhynchotreta cf. borealis (Schlotheim).
Protobactrites sp.
Encrinurus cf. punctatus.
cf. Phacops sp.

He summarizes the age of the beds as follows:—"The age of the fossil assemblage from the Geological Survey locality Ba65 points mainly to a Melbournian age. At the same time there is an upward tendency in the stratigraphical scale as shown by the trilobites.

The occurrence of such a restricted Melbournian fossil, however, as *Chonetes melbournensis,* together with *Protobactites* and *Camarotoechia decemplicata,* supports the idea of a Melbournian age."

From these sections the graptolite evidence is conclusive, and points definitely to a horizon about the zone of *Climacograptus peltifer* and *Mesograptus multidens* in the Upper Ordovician, and that too not in the higher beds. The grits are interbedded with the graptolite shales, and one is forced by such evidence to think that the shelly fossils have a much longer time-range than has been hitherto supposed.

The following is a revised list of the fossil forms obtained from Ba64, the old Geological Survey locality:—

Diplograptus (Orthograptus) calcaratus var. vulgatus Lapw.
D. (Glyptograptus) teretiusculus (Hisinger).
D. (Glyptograptus) teretiusculus var. siccatus E. and W.
D. spp.
Climacograptus bicornis (Hall).
C. bicornis var. peltifer Lapw.
C. cf. scharenbergi Lapw.
C. spp.
Dicranograptus ramosus var. spinifer Lapw.
D. cf. zic zac Lapw.
D. sp.
Dicellograptus divaricatus Hall.
D. intortus Lapw.
D. sextans Hall.
D. sp.
? Glossograptus.
cf. Lasiograptus (Hallograptus) mucronatus (Hall).
Leptograptus spp.
Didymograptus spp.

South along Jackson's Creek no locality with well-preserved forms was found, but in the railway cutting at Rupertswood Siding richly fossiliferous beds outcrop. *Diplograptus truncatus*

in its varietal form is very common and occurs almost to the exclusion of other forms, which include *Cryptograptus tricornis, Diplograptus* (*Orthograptus*) cf. *pageanus* and a small *Climacograptus,* possibly new. The absence of the *Dicranograpti* is striking, and similar beds have been found elsewhere underlying the beds with *Dicranograptus* and *Dicellograptus.*

From a small washout (Loc. 25) east of the road from Sunbury to Gisborne the following forms were identified:—

Diplograptus (Orthograptus) truncatus var. abbreviatus E. and W.
Diplograptus (Orthograptus) calcaratus Lapw.
D. (Amplexograptus) perexcavatus Lapw.
D. spp.
Climacograptus bicornis (Hall).
C. caudatus Lapw.
Dicranograptus nicholsoni Hopk.
D. cf. furcatus Hall.
D. sp.
Dicellograptus sp.

The characteristic feature of this locality is the abundance of the *Orthograpti.*

(*c*) Area between Sunbury and Sydenham.

The close folding of competent and incompetent bands together with faulting makes the structure of the area between Sunbury and Sydenham complicated. Fossils are abundant, but only at a few favorable localities have extensive collections been made.

(*d*) Jackson's Creek sections.

In Asylum Creek, south of Sunbury, several black graptolite bands were found, one of which (Loc. 12) yielded the following forms:—

Climacograptus bicornis (Hall).
Diplograptus cf. calcaratus Lapw.
D. truncatus var. abbreviatus E. and W.
D. spp.

Massive grit beds occur on Jackson's Creek near the mouth of Asylum Gully similar to the grits that occur on Jackson's Creek near Clarkefield.

The next good fossiliferous area is that near the Old Survey localities Ba61, 62, and 63 (Q.S. 7 S.E.). Some forms were recorded by McCoy(28) from these localities and ascribed to the Bala.

The actual bands of the Survey cannot be located with certainty, but as the bend of the creek has fossiliferous rocks

throughout and the assemblage is approximately the same, they will be treated as one locality (Loc. 61). The following forms have been identified :—

Leptograptus sp.
Dicellograptus intortus Lapw.
D. divaricatus Hall.
Dicranograptus brevicaulis E. and W.
D. nicholsoni Hopk.
D. furcatus var. minimus Lapw.
Climacograptus antiquus Lapw.
Diplograptus (Orthog.) calcaratus var. priscus E. and W.
D. calcaratus var. vulgatus Lapw.
D. spp.
Nemagraptus gracilis (Hall).

To the east, in a small gully commencing near the point of eruption on the north, the following forms were found (Loc. 4) :—

Diplograptus calcaratus var. vulgatus Lapw.
D. truncatus var. intermedius E. and W.
Dicellograptus moffatensis Carr.
Dicranograptus cf. zic zac Lapw.
D. cf. ramosus (Hall).
Climacograptus bicornis (Hall).
C. bicornis var. peltifer Lapw.

In blue beds interbedded with grits (Loc. 3) on the hill slope 50 yards downstream were found *Dicranograptus nicholsoni* and *Diplograptus* spp. Still further downstream in a cliff on the south side of the river, the following forms were found in hard light blue mudstones (Loc. 2) :—

Dicranograptus nicholsoni Hopk.
Climacograptus antiquus var. lineatus E. and W.
C. antiquus var. bursifer E. and W.
Diplograptus (Amplexograptus) perexcavatus Lapw.
Leptograptus sp.

Further downstream on the south side of the stream some well preserved forms were found in thin bedded, brown mudstone (Loc. 1) :—

Diplograptus (Orthog.) quadrimucronatus (Hall).
D. (Orthog.) calcaratus var. vulgatus Lapw.
Climacograptus cf. styloideus Lapw.
C. minimus (Carr).
Dicellograptus affinis T. S. Hall.
D. didymus MS.
D. cf. complanatus Lapw.

The next fossiliferous area is at the mouth of Column Gully, a locality discovered by James(20).

Opposite the mouth of Column Gully occurs a band (Loc. 10) with abundant Diplograptidae which gave the following forms:—

Diplograptus (Orthograptus) truncatus var. socialis Lapw.
D. (Orthog.) cf. var. abbreviatus E. and W.
Climacograptus cf. scalaris var. miserabilis E. and W.
Dicellograptus cf. complanatus Lapw.

At about 100 yards upstream, on the east bank, the following forms were obtained (Loc. 9):—

Climacograptus bicornis (Hall).
C. missilis H. and K.
Diplograptus sp.
Dicellograptus cf. caduceus Lapw.

The association is characteristic for beds high in the Upper Ordovician, and is distinct from that with *Nemagraptus*. James's record of that form at this locality is inconsistent with what we have observed elsewhere.

From the blue mudstones downstream, we were unable to obtain any fossils.

(*B*) *Emu Creek Sections.*

There are few exposures along Emu Creek to the east of Clarkefield. Graptolites may be obtained in the patch near the north boundary of Q.S. 7 N.E., but a good locality is found about 1½ miles downstream in the patch which is erroneously coloured as Tertiary on the Quarter Sheet. In the bluish mudstones, the following forms are well preserved (Loc. 11):—

Dicellograptus elegans Carr.
D. spp. nov.
Climacograptus tubuliferus Lapw.
C. minimus (Carr).
Diplograptus truncatus cf. var. abbreviatus E. and W.

Near the mouth of Emu Creek exposures are more plentiful. The beds are very closely folded, and in this respect remind one of the area to the north-east of Diggers' Rest. Fossils are difficult to obtain, due in part, no doubt, to the metamorphism of the Bulla granite.

White pipeclay outcrops in Allot. 24, a locality mentioned by McCoy(28), where *Diplograptus mucronatus* is "very abundant and beautifully preserved in the white decomposed (Llandeilo flags) soft shale (Ba67) . . ." Ba67, however, is the locality at the junction of Riddell's Creek and Jackson's Creek, as has

been pointed out by Harris and Crawford(17). The following forms were found (Loc. 17) :—

Climacograptus bicornis (Hall).
Diplograptus quadrimucronatus (Hall).
D. quadrimucronatus var. spinigerus Lapw.

Further down the main creek the typical blue thin-bedded Ordovician rocks outcrop, but up to the present no fossils have been found in them.

(*C*) *Deep Creek Sections.*

Upstream from typical Silurian worm beds, thin-bedded blue mudstones occur. Locality 16 is in a small washout about 3 chains from its junction with Deep Creek. Here the following forms were obtained :—

Diplograptus calcaratus Lapw.
D. calcaratus var. indet.
Climacograptus sp.
Dicellograptus cf. didymus (MS.).
D. affinis H and K.
D. sp.
Pleurograptus linearis var. dispansus (MS.).

Near the mouth of the next tributary a similar association was found (Loc. 18) :—

Diplograptus quadrimucronatus (Hall).
D. calcaratus Lapw.
Climacograptus bicornis (Hall).
Dicellograptus cf. complanatus var. ornatus E. and W.
Pleurograptus sp.

Further upstream thin-bedded mudstones occur, in which fossils, usually too poor for specific identification, may be obtained. The next bands with well preserved fossils are near the Survey locality (F4).

The following forms were obtained from sandy beds at creek level :—

Diplograptus (Glyptograptus) tamariscus Nich.
Retiograptus pulcherrimus Keble and Harris (MS.).

In the brown mudstones (Loc. 15) further up the hill slopes the following forms were found :—

Dicellograptus spp. nov.
D. cf. complanatus var. ornatus E. and W.
D. affinis T. S. Hall.
Diplograptus truncatus Lapw.
Diplograptus truncatus var. abbreviatus E. and W .
Diplograptus truncatus cf. var. intermedius E. and W.
Diplograptus truncatus var. pauperatus E. and W.
Climacograptus cf. exiguus H. and K.
C. sp.
cf. Pleurograptus sp.

Typical thin-bedded variegated mudstones, shales, and sandstones follow upstream until the typical green mudstones and sandstones of the Silurian are reached. Just before this lithological change (approximately 2 chains beneath it) is Loc. 27, from which only two forms may be recorded:—

Diplograptus cf. calcaratus.
? Pleurograptus sp.

(D) Konagaderrer Creek Sections.

Near the mouth of the creek is locality 13, where *Diplograptus (Orthograptus) calcaratus* was recognized. Further upstream is locality 28, where the same form, together with *Diplograptus truncatus* var. *intermedius, Climacograptus* cf. *scalaris,* and *Dicellograptus* sp., was found.

Locality 22, some distance upstream, yielded:—

Diplograptus truncatus var. abbreviatus E. and W.
D. truncatus var. socialis Lapw.
Climacograptus scalaris var. miserabilis E. and W.

About 100 yards upstream from a small waterfall some well-preserved forms (Loc. 21) were obtained:—

Dicellograptus forchammeri Geinitz.
D. forchammeri var. flexuosus Lapw.
D. havelockensis (MS.).
Diplograptus (Orthograptus) insectiformis var. vagus (MS.).
Diplograptus (Orthograptus) quadrimucronatus (Hall).
Climacograptus scalaris cf. var. normalis Lapw.
C. scalaris var. nov. (MS.).
Dictyonema sp.

On the crest of an anticline with a strong northerly pitch of 20 deg. the following forms were obtained (Loc. 20):—

Dicellograptus elegans Carr.
D. pumilus Lapw.
Diplograptus (Orthograptus) insectiformis var. vagus (MS.).
D. truncatus var. intermedius E. and W.
Climacograptus cf. tubuliferus Lapw.
C. scalaris var. miserabilis E. and W.
C. cf. minimus (Carr).

One would expect from the close folding of the area that the beds along Konagaderrer Creek would be on approximately the same horizon, and this seems to be so.

V. Previous Subdivision of Upper Ordovician in Australasian Province.

Hitherto the only attempts at a serial subdivision of the Upper Ordovician of the Australasian Province have been made by Harris and Crawford(17), who dealt with portion of the area under discussion, and by Keble and Benson(25), who subdivided the Upper Ordovician of New Zealand.

Harris and Crawford's tentative subdivision was as follows:—

1. (Lowest) Beds with Didymograptus spp. without Dicellograptus and Dicranograptus.
2. Beds with Didymograptus and Dicellograptus, without Dicranograptus.
3. Beds with Dicranograptus, Dicellograptus, but without Didymograptus.

They also point out that there are probably *Diplograptus* beds above their Bed 3.

Their Bed 1 is represented by the fauna at Locality Ba67, Q.S. 6 N.E., but overlying this and in a continuous exposure, a bed has been found with both *Dicellograptus* and *Dicranograptus* in an assemblage similar to the main body at Ba67. Actually Harris and Crawford's subdivision comprises the Gisbornian and part of the Eastonian as proposed here.

Keble and Benson tentatively divided the Mount Arthur (Upper Ordovocian) Series of New Zealand into the Lodestone and Leslie zones. Some of the species on which their zoning has been based have not yet been correlated in Victoria, but probably the three divisions proposed here occur.

VI. Proposed revised Serial Subdivision in Victoria.

The Upper Ordovician may be grouped into three series, two of which are well represented in this area, while the middle one is better developed elsewhere. Each of these series is capable of more or less close zoning, but while some of the zones are well developed, others are missing, or better known in other parts of the State. It is believed that the serial subdivision adopted here will be applicable to the Upper Ordovician of Victoria generally, but the full zoning of the beds must be left until other areas of the State can be examined in detail.

The serial arrangement proposed is—

3. Bolindian.
2. Eastonian.
1. Gisbornian (oldest).

The names are selected from those localities where the series are best exemplified. Gisbornian is so named after the township of Gisborne, and Bolindian from the parish of Bolinda. Eastonian is derived from Mt. Easton, where the graptolites belonging to the series are profusely and beautifully developed(26).

In brief, the typical forms of each of these series are as follows:—

(i) *Gisbornian.*

Didymograptus spp.
Diplograptus teretiusculus sp. et var.
D. multidens.
Nemagraptus sp.

Climacograptus peltifer.
C. antiquus.
Dicranograptus brevicaulis.
Dicellograptus intortus.
D. sextans.
D. divaricatus et var.
Glossograptus hincksii (probably lowest beds of series only).

(ii) *Eastonian.*

The Dicranograptidae reach their acmic and paracmic stages and approach extinction in this period. The most characteristic feature of this series is, however, the numerous development of Diplograpti of the *Orthograptus* type, belonging mainly to the *O. calcaratus, O. truncatus,* and *O. quadrimucronatus* groups. The *O. quadrimucronatus* group reaches its acme rather later than the other groups and ranges into the base of the Bolindian. In the field, the predominant *Orthograptus* element, in typical association, cannot be mistaken in defining the series. A characteristic assemblage would be:—

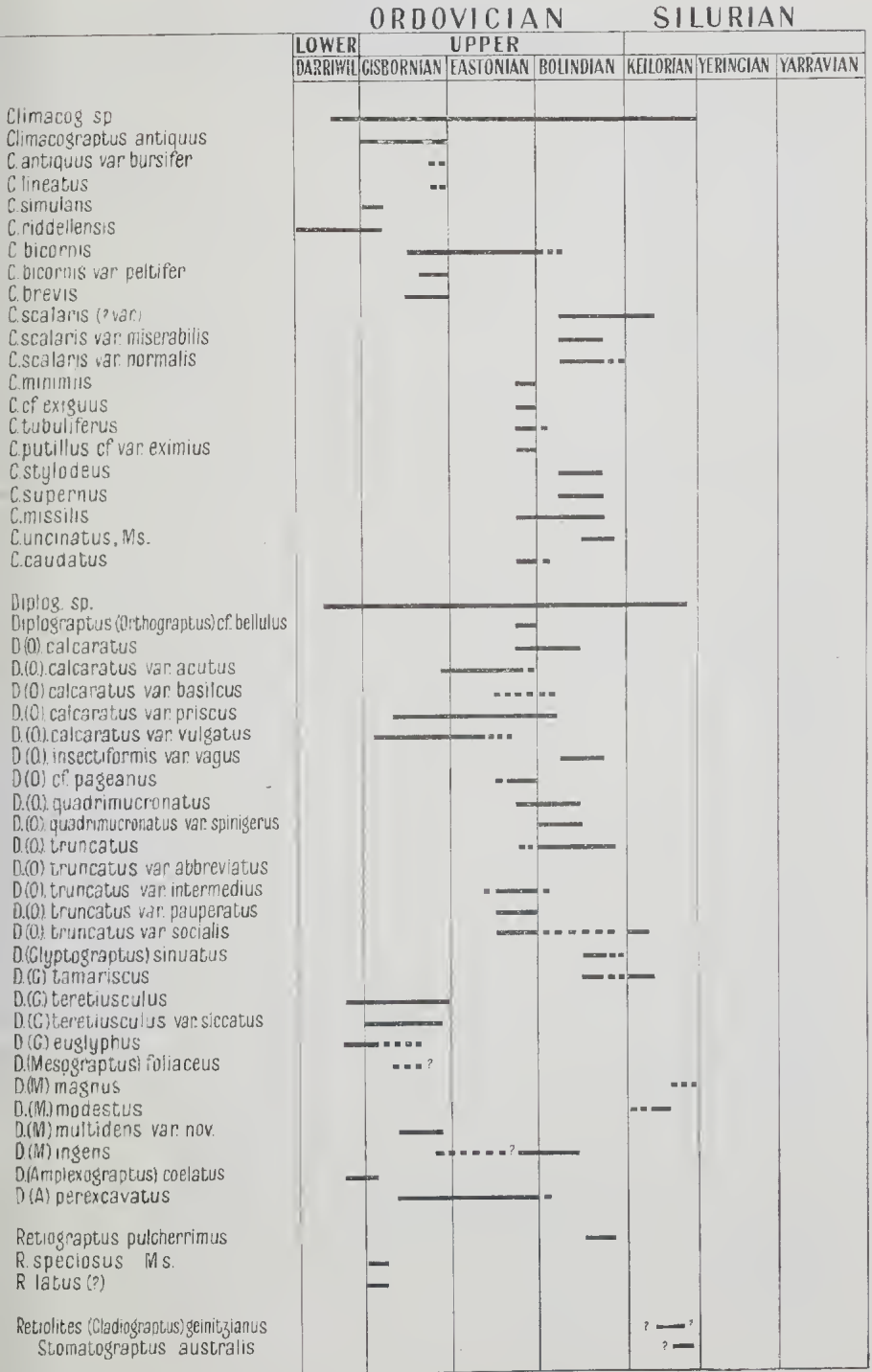
Diplograptus (Orthograptus) calcaratus group, numerous.
D. (Orthograptus) truncatus group, numerous.
D. (Orthograptus) quadrimucronatus group, numerous.
D. (Amplexograptus) perexcavatus.
Dicranograptus ramosus.
D. nicholsoni.
D. hians et var.
Dicellograptus elegans.
D. spp.
Climacograptus tubuliferus.
C. caudatus.

Diplograptus quadrimucronatus and *Dicellograptus elegans* are typical of the highest beds of the series.

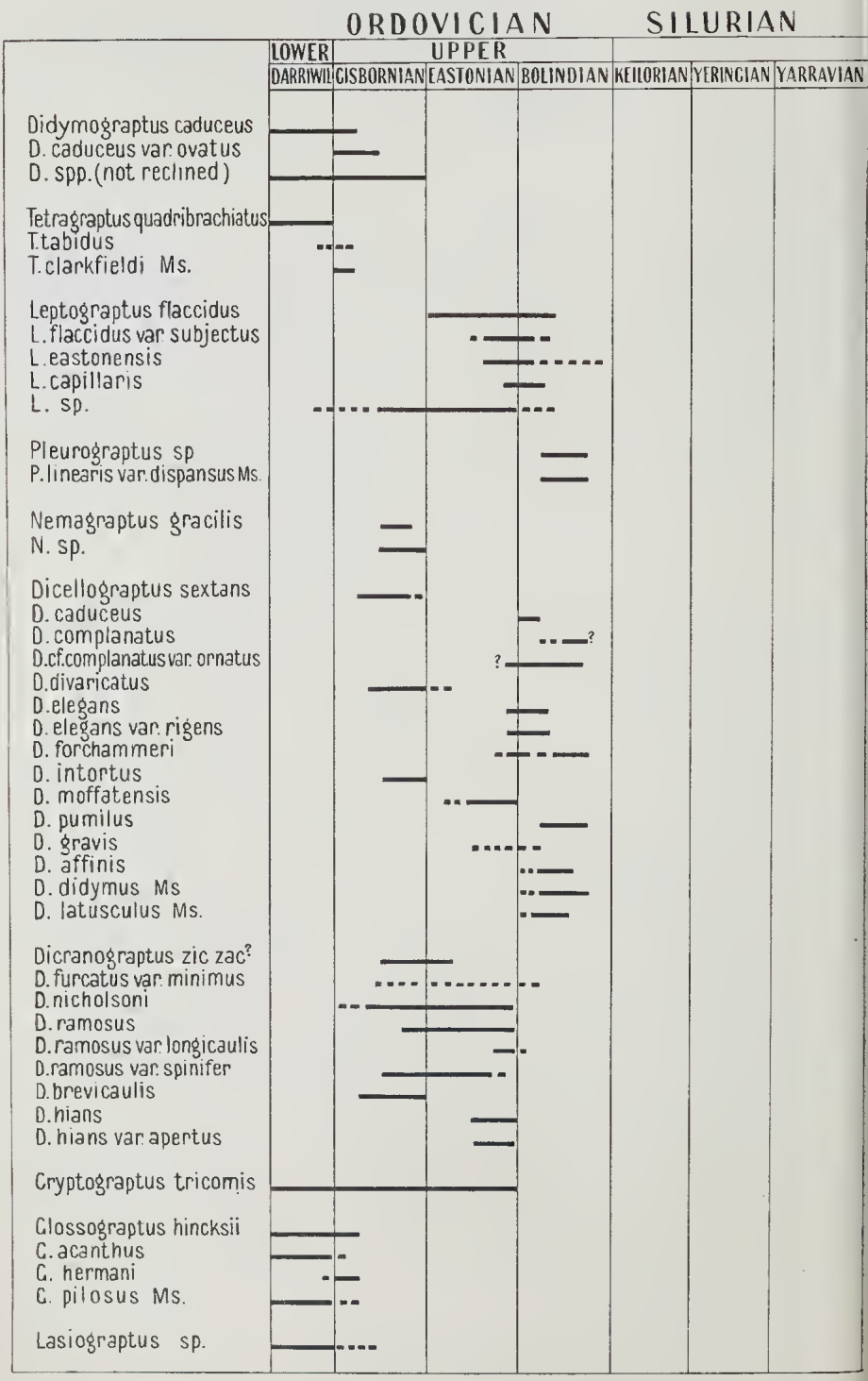
(iii) *Bolindian.*

With one exception, the *Dicranograpti* do not range into the Bolindian. The *Diplograpti* still predominate and the *Climacograpti* are the smaller forms belonging to the *C. scalaris* group. *Dicellograptus affinis,* and a *Dicellograptus* allied to *D. complanatus,* are characteristic. High beds also show *Retiograptus pulcherrimus* (Keble and Harris MS.), *Climacograptus uncinatus* (K. and H. MS.), and other forms whose faunal range is imperfectly known. *Diplograptus* (*Glyptograptus*) *tamariscus,* wholly Silurian in Britain(9) first makes its appearance in this series in Victoria and ranges up into the Silurian. The lowest part of the series is characterized by *D. quadrimuconatus* et var. and *D. elegans,* and the middle beds by a form of *Pleurograptus* differing from the described forms. Further work may show that the affinities of the lower part of the Bolindian is with the Eastonian, but so far it has been found only at two or, possibly, three localities closely associated with higher Bolindian beds.

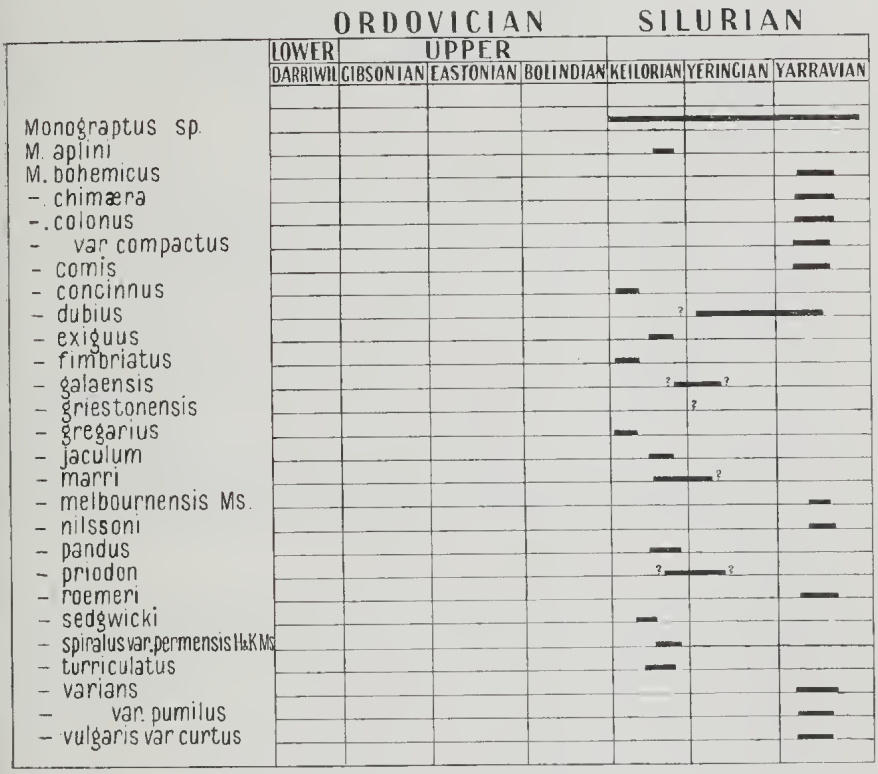
TABLES OF RANGES OF FORMS SO FAR DETERMINED.



TABLES OF RANGES—*continued.*



TABLES OF RANGES—*continued.*



N.B.—These Tables are tentative only.

VII. Correlation with British Occurences (9).

Apart from some minor details, the Gisbornian is approximately the equivalent of the British Llandeilian. In Victoria, *Diplograptus* (*Glyptograptus*) *teretiusculus* makes its appearance in the higher Lower Ordovician bed (D1), which has no equivalent in the British succession. It is common at Loc. Ba67, an association comparable with part of the *D.* (*G.*) *teretiusculus* zone of Britain. In Victoria the beds with *Nemagraptus gracilis, C. peltifer* and *Diplograptus* (*Mesograptus*) *multidens* may be correlated with those zones in Britain. *M. multidens* is more characteristic of the lower part of the zone where *Nemagraptus* is rarely found and *C. peltifer* ranges higher. The Eastonian embraces approximately the lower two zones of the Caradocian, the zone of *Climacograptus wilsoni* having not yet been established definitely. *Dicranograptus clingani* is apparently absent from beds, the fauna of which otherwise corresponds fairly well to that British zone. The Bolindian corresponds to

the zone of *Pleurograptus linearis* and to the Ashgillian of Britain; the reason for placing *Pleurograptus* beds in the Bolindian has been already explained. The highest part of the series is imperfectly known, as most of the area comprising it is sparingly fossiliferous; *Dicellograptus anceps* has not been found.

VIII. Details of Distribution and Horizons.

(*a*) *The Gisbornian.*—Both the stratigraphy and palaeontology show conclusively that the Gisbornian is the lowest series in the Upper Ordovician. Ba67 is on the flanks of the Mount William anticlinorium; on this line, further to the north, Heathcotian and Lower Ordovician rocks outcrop(45).

The fauna of Ba67 is one of those transition faunas which present some difficulty as to whether they should be placed in the Upper or Lower Ordovician. *Tetragraptus,* whose presence is generally taken to indicate Lower Ordovician beds, occurs sparingly at Ba67. The forms, over-specialized and monotypic, are obviously the last expression of that genus, and cannot be mistaken for *Tetragraptus quadribrachiatus,* which occurs in the Darriwil.

The faunal list shows that the Upper Ordovician element is slightly better developed than the Lower Ordovician.

	Darriwil (16) D1	Gisbornian lowest beds.
Didymograptus cuspidatus	x	—
D. caduceus	c	r
D. ovatus	r	r
D. forcipiformis	x	—
D. nodusus	cc	—
Tetragraptus clarkefieldi (MSS.)	—	x
T. quadribrachiatus	x	—
T. cf. tabidus	—	x
Phyllograptus nobilis	x	—
Brachiograptus etaformis	x	—
Atopograptus woodwardi	x	—
Trigonograptus gen.	?	—
Diplograptus euglyphus et var.	x	x
D. coelatus	x	?
D. teretiusculus	x	x
Climacograptus riddellensis	x	x
C. antiquus et var.	?	x
Cryptograptus tricornis	x	x
Glossograptus hincksii	x	x
Retiograptus speciosus	—	x

x = forms present; c = common; cc = very common; r = rare; — = absent.

Since a transition fauna is evidence of a normal succession and an arbitrary boundary must be drawn to separate the Upper from the Lower Ordovician, the fauna of Ba67 appears to us most suitable to occupy the basal position of the Upper Ordovician.

The upper bed of locality Ba67 marks the incoming of the Dicranograptidae in an association otherwise the same as the lower bed. In the same synclinorium, but stratigraphically higher, beds with *Nemagraptus* and *C. bicornis* outcrop near the head of Evans' Creek. The association at Ba61 is essentially the same, and the fauna has much in common with the upper bed at Ba67.

A little to the east of Ba67 beds outcrop which contain *Climacograptus peltifer* and *Diplograptus* (*Mesograptus*) *multidens,* in which only one specimen of *Nemagraptus* was found. Ba64 contains a similar fauna, in which several *Didymograpti* have been recorded, indicating the upper limit of this characteristic Lower Ordovician genus. The zones of *Glyptograptus teretiusculus, Nemagraptus gracilis,* and *Climacograptus peltifer,* of the British succession, thus have their equivalents in the Gisbornian.

(*b*) *The Eastonian.*—On the whole, fossiliferous beds of the Eastonian are poorly developed in this area as compared with the Mount Easton area and on Emu Creek to the west of Romsey.

In the Clarkefield synclinorium, massive grits, which first appear in the middle of the Gisbornian, are strongly developed in the Eastonian, and show that conditions that favoured this phase of sedimentation were recurrent over an extended period. The mudstones and shales between these grit bands are badly shattered and slickensided so that there is difficulty in obtaining graptolites well enough preserved for accurate determination.

Towards the centre of the Clarkefield synclinorium highly fossiliferous Eastonian beds occur near the Sunbury-Gisborne back road. The assemblage is similar to that at Emu Creek and parts of Mount Easton. The stratigraphical position of the beds is clear as on either flank of the synclinorium Gisbornian beds outcrop, as at Ba67, the head of Evans' Creek, and at Ba64.

Both at Emu Creek and at Mount Easton(26), the upper beds of the Eastonian are characterized by abundant *Dicranograpti* together with forms that range into the lower Bolindian. East of the Clarkefield synclinorium, Eastonian beds outcrop in Asylum Gully and to the east of Ba61.

The crowded development in some beds of the Orthograptid group has already been commented on. Such occur at the Rupertswood Siding, Emu, and Konagaderrer Creeks, where they are beneath Eastonian *Dicranograptus* beds.

The upper part of the Eastonian corresponds to the zone of *Dicranograptus clingani* in the British succession(9), although the zonal fossil has not yet been recorded in Australia.

(*c*) *Bolindian.*

The Bolindian beds, as one would expect, are best developed in that part of the area adjacent to the Silurian. So far we have only found in it one species of *Dicranograptus* (*D.* cf. *furcatus*) and even that form is restricted to the basal beds.

Diplograptus quadrimucronatus et var., *D. truncatus* sp. et var., *Climacograptus tubuliferus*, and *Dicellograptus elegans* appear at the top of the Eastonian, where they occur in association with various *Dicranograpti* and range into the Bolindian.

Pleurograptus sp. characterizes the middle portion of the Bolindian, while a still higher assemblage is that of *Retiograptus pulcherrimus* (K. and H.), *Climacograptus* (K. and H.), *Leptograptus eastonensis*, and *Dicellograpti* with narrow stipes. The *Pleurograptus* present differs from the British forms in the distance between the branches, which is much greater in our form. Forms such as *Dicellograptus anceps* and *Dicellograptus complanatus*, which are well developed in Great Britain, are rare here, but *Diplograptus tamariscus* and *D. sinuatus*, which in Britain are Lower Silurian, make their appearance in the upper beds of the Bolindian. Another form present, which in Britain is confined to the Silurian, is *Diplog.* (*Orthog.*) *insectiformis*. The varietal form (var. *vagus*) is, however, well developed in beds with *Dicellograptus forchammeri*.

Typical Bolindian beds occur in this area near the junction of Column Gully and Jackson's Creek, along Deep Creek, some distance upstream from Bulla, locality 11 on Emu Creek, along Konagaderrer Creek, and at locality 1 to the east of Ba61.

IX. General Structure of the Bulla-Sunbury Area.

The stratigraphical evidence and the zoning as determined enable the structure of the area to be elucidated broadly. Without the zoning it would be impossible to hazard a guess at the horizon of certain isolated areas whose stratigraphical position can thus be determined.

It has been found impossible to mark in all the minor folds which modify the general structure or to show in detail the extent of the various series. Detailed work will, no doubt, amplify the map, but sufficient evidence has been gathered to indicate the main structural features of this area.

To the north-west is the southern continuation of the Mount William anticlinorium. On the flanks of this, Gisbornian beds appear. The Clarkefield synclinorium, with a development of Eastonian beds in the southern part of it at least, lies between this line and the Sunbury anticlinorium, which is shown by the reappearance of the Gisbornian beds near Ba65.

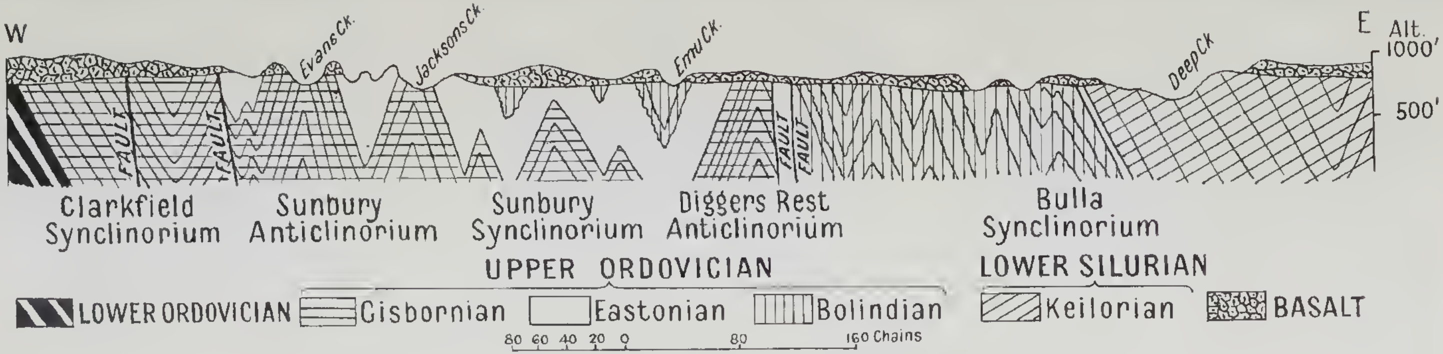


Fig 2.—Diagrammatic section from Evan's Creek to Deep Creek, near Konagaderrer.

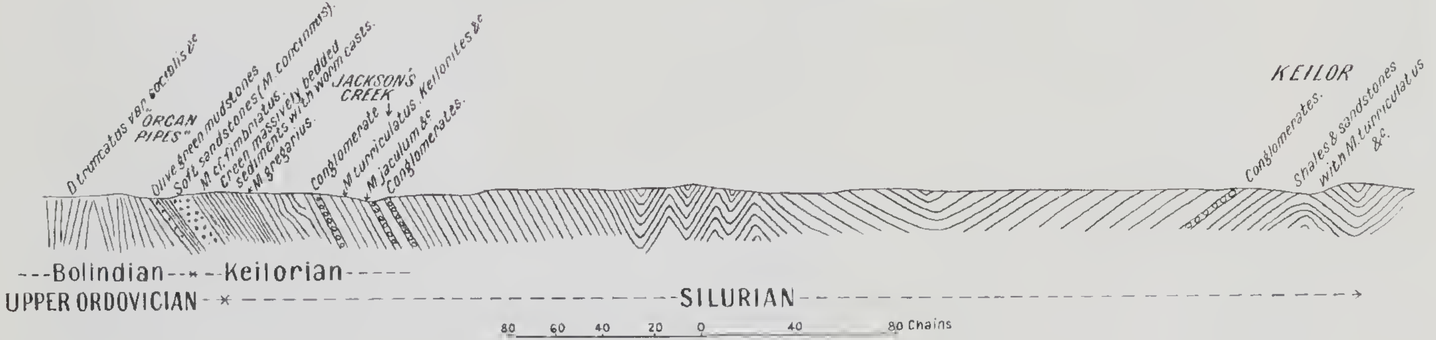


Fig. 3.—Beds exposed in Jackson's Creek and Keilor on a projected line (S. 47° E.) from Organ Pipes to Keilor.

The next appearance of Gisbornian beds is in the Diggers' Rest anticlinorium which passes through Ba61. Between these two anticlinal lines is the Sunbury synclinorium. Most of this area is covered by basalt, but at Rupertswood and Asylum Gully Eastonian beds occur, while Bolindian outcrops at Loc. 11 on Emu Creek.

Further to the east is the Bulla synclinorium, in which the Silurian beds make their appearance. It is in this synclinal area that the Bolindian beds are best developed.

These structures have a N.N.E. to S.S.W. strike over most of the area, but both to the north and the south the trend line pursues a more meridional course.

To work out the structure in detail, which is complicated by strike faulting and thrusting, would take a much longer time than we have been able to devote to it, and would involve what will ultimately have to be done, intensive collecting from areas which we have been compelled to treat only cursorily.

X. Boundary of Upper Ordovician and Silurian.

The Silurian-Ordovician contact west of the meridian of Keilor may be fixed within narrow limits, and it may be shown incidentally that the junction is conformable, that the beds between it and Keilor are not Melbournian but Keilorian.

In five areas west of Keilor the Upper Ordovician and Silurian come into close relationship. Owing to imperfect exposures or the covering of basalt, the actual contact is not clearly seen, but the gap in each case is small, and one passes from thin-bedded Upper Ordovician into the massive green-coloured mudstones and sandstones of Silurian age. The sections to be discussed are 1, the Jackson's Creek section near Sydenham; 2, near the mouth of Emu Creek; 3, Deep Creek, to the north of Wildwood; 4, Konagaderrer.

1. *Jackson's Creek, near Sydenham* (Figs. 3 and 4).

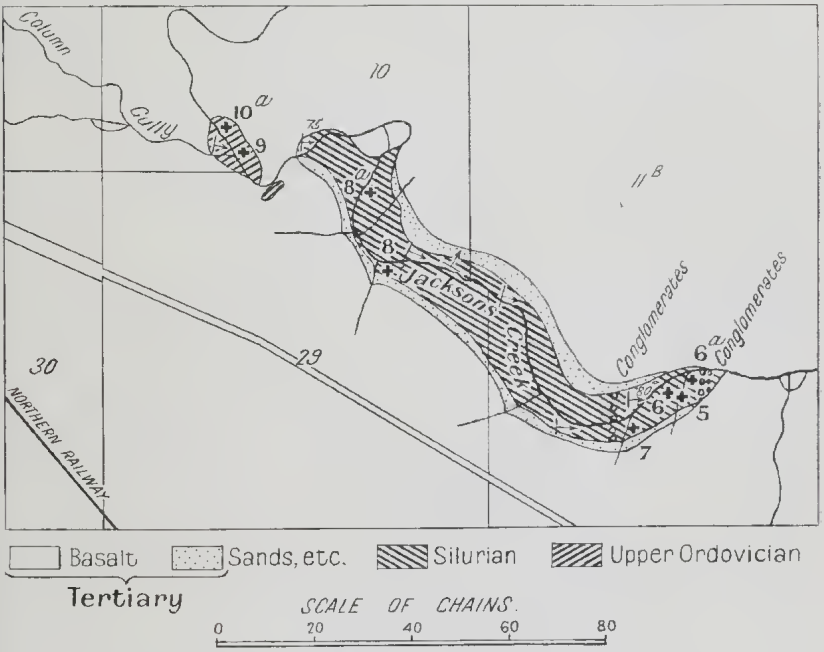
Typical thin-bedded brown or blue mudstones and sandstones with Bolindian fossils, and dipping to the east, occur near the junction of Column Gully and Jackson's Creek. These are continuous with blue mudstones, up to the present unfossiliferous, which outcrop further downstream. These dip at high angles to the east, become vertical and then dip to the west. Basalt then reaches creek level, but a small "window" exposes some beds similar in character to the fossiliferous Upper Ordovician further upstream.

Before reaching the "Organ Pipes" massive bedded green hackly shales, exhibiting nodular weathering, are exposed along

the north bank of the creek. Downstream from the "Organ Pipes" are soft sandstones (Loc. 8A) from which we obtained—

Monograptus cf. concinnus Lapw.
Diplograptus (Glyptograptus) tamariscus Nich.
Diplograptus sinuatus Nich.
Climacograptus sp.

The beds were first thought to be Upper Ordovician in age, as the *Glyptograpti* present had been found only in association with *Dicellograptus*, although at the time this section could not be correlated with others from a lithological stand-point. On a subsequent visit we were fortunate enough to obtain two speci-



Text-fig. 4.—Jackson's Creek, near Sydenham.

mens of *Monograptus* which we have compared with *M. concinnus*. Approximately on the same line of strike, in a dark-green sandstone, we obtained the following forms:—

Monograptus cf. fimbriatus (Nicholson).
Diplograptus sp.
D. (Glyptog.) tamariscus Nich.
Climacograptus sp.

Further to the east are the "worm track" beds of James (20). In them are several bands of graptolites among them being *Monograptus* cf. *fimbriatus*, a restricted Llandoverian form. Loc. 7 is in a small washout on the downstream side of the

lowest conglomerate [C1 of James(20)] on Jackson's Creek. The only form obtained was *Monograptus sedgwicki,* and at the mouth of the washout James records *Keilorites.*

Loc. 6 is probably the one recorded by James with *Monograptus* sp. and *Keilorites.* From this bed we have been able to identify, in addition—

Monograptus turriculatus (Barrande).
M. marri (common) Perner.
M. cf. crispus Lapw.
Diplograptus sp.
Keilorites sp.

In the small washout downstream from these beds is Loc. 5, a richly fossiliferous bed which yielded the following forms:—

M. jaculum (Lapworth).
M. priodon (Bronn).
M. marri Perner.
M. cf. sedgwicki (Portlock).

At the mouth of this washout gill plumes of Keilorites were found at Loc. 6A.

Further downstream are two small conglomerate bands between which Harris (verb. cit.) obtained *Monograptus* sp.

2. *Near the Mouth of Emu Creek* (Fig. 5).

On Emu Creek, about ½ mile above its junction with Deep Creek, indurated thin-bedded blue shales occur, almost certainly Upper Ordovician, as they are apparently a continuation of the series which still further to the west yielded Upper Ordovician graptolites. These rocks strike N. 25°–30° E.

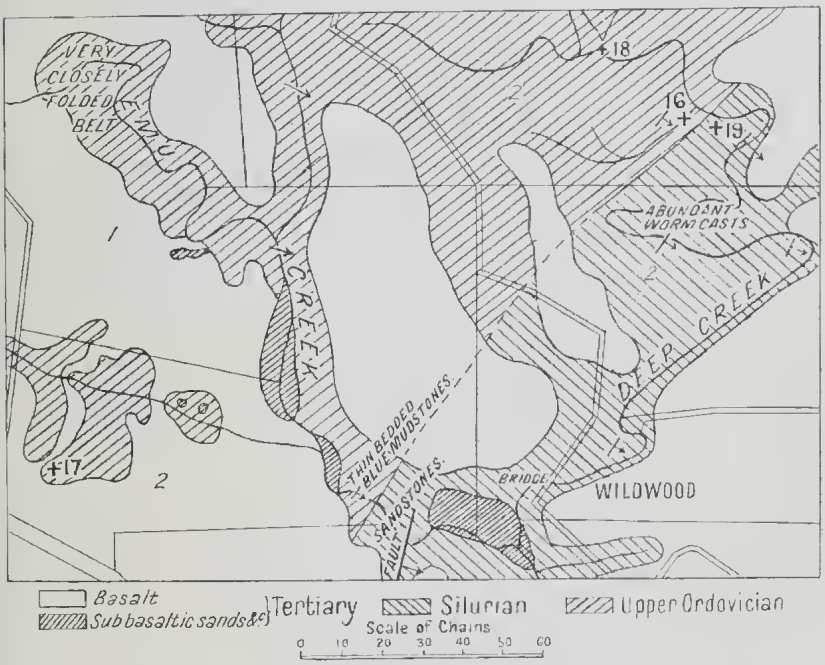
At the next exposure, a few chains downstream, a distinct lithological change is noted. The rocks are more massively bedded, and have the characteristic green colour of the typical Silurian beds. Along the meander further downstream are massive soft brown sandstones, while succeeding these are beds similar to those already described along Jackson's Creek. These beds have every appearance of relationship with rocks of Silurian age in other parts of the area, and although no fossils were obtained, it is very probable that intensive search, difficult in such an extensive exposure, would reveal the presence of *Monograptus.*

This cliff section shows faulting and minor folding which may correspond with the slight "roll" detected in the Jackson's Creek section.

Apart from these minor contortions, the dip of all the beds is easterly at a high angle, and the strike in both systems is N. 25°–30°

Further to the south, but at a higher horizon, fossils are to be obtained at Loc. Ba60. From this locality, Chapman(8) has identified :—

Lindstroemia conspicua Chapman.
Heliolites sp.
Crinoidea.
Keilorites cf. crassituba (Chapman).
Ceramporella sp.
? Orthis sp.
cf. Edmondia perobliqua Chapman.
cf. Pleurotomaria.
Murchisonia sp.



Text-fig. 5.—Sketch Map of Area near Wildwood.

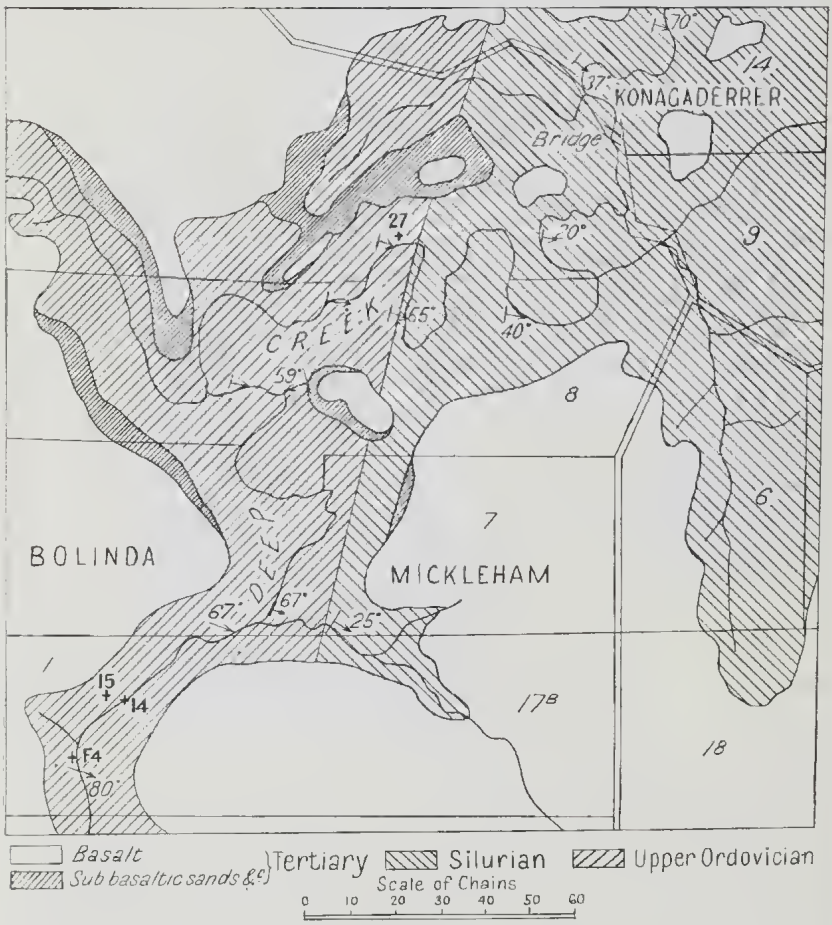
Concerning these, he remarks: "The collective evidence of the suite of fossils from the Geological Survey locality Ba60 is in favour of a Melbournian age for these fossiliferous sandstones. This conclusion is supported by the presence of such typically older Silurian forms as *Lindstroemia conspicua, Heliolites megastomum, Keilorites* cf. *crassituba,* and cf. *Edmondia perobliqua.* The polyzoan *Ceramporella* introduces an Ordovician element into the facies, but the balance of the evidence is in favour of its Melbournian age."

From the graptolite evidence of the area further south, it appears that these shelly fossils are beneath the rocks typically developed at Melbourne, and in all probability belong somewhere near the top of the Keilorian as proposed by us.

3. *Deep Creek to the North of Wildwood* (Fig. 5).

About a mile upstream from the bridge at Wildwood good exposures are seen along Deep Creek and some of its tributaries.

The beds at Loc. 16 are the usual thin-bedded blue mudstones and interbedded thin sandstones. The beds have typical Bolindian fossils. On the opposite side of Deep Creek the beds have lost



Text-fig. 6.—Sketch Map of Area near Konagaderrer.

their thin-bedded character, the sandstones have developed a green colour, but the intervening shales are still blue, but are indurated.

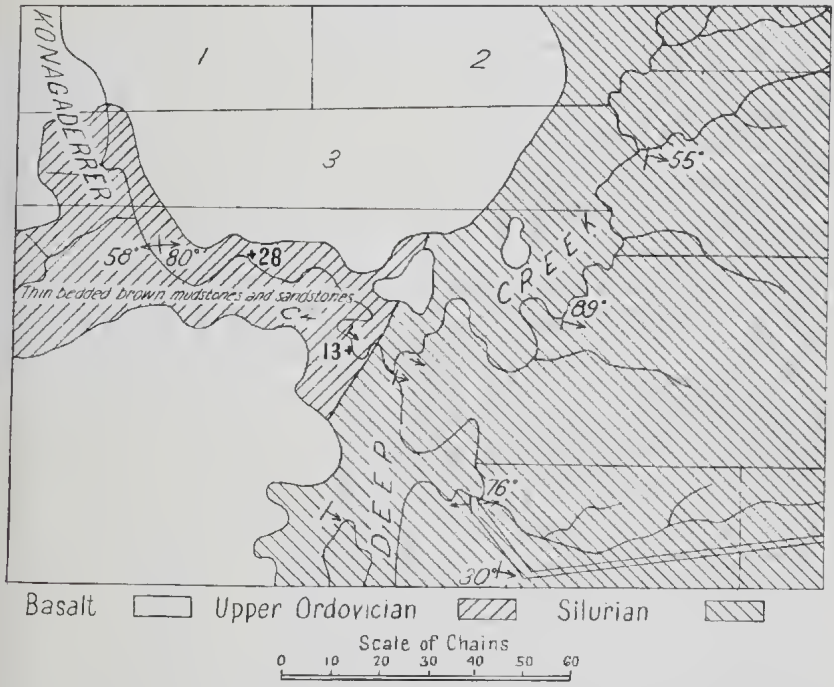
On the same side of Deep Creek as Loc. 16 are black, almost cherty beds, in which indistinct graptolites can be seen. These are small forms totally distinct from those of the nearest Upper Ordovician localities.

Still further downstream the beds have the typical Silurian aspect—massive green-coloured sandstones and mudstones, the latter being full of what may be called, for lack of a better name, "worm tracks."

On the south-west side of the next meander downstream can be seen the soft sandstones already noted in the Jackson's Creek and Deep Creek sections. As in those sections, the dips and strike of the two systems are similar, but the strike is more easterly than in the Emu Creek section.

4. *Konagaderrer* (Figs. 6 and 7).

The next bridge upstream along Deep Creek from Wildwood is Konagaderrer, and in this area two traverses give sections from



TEXT-FIG. 7.—Sketch Map of Area near mouth of Konagaderrer Creek.

the Upper Ordovician to the Silurian. One (*a*) is below the bridge, while the other (*b*) is a few miles to the north near the junction of Konagaderrer Creek and Deep Creek.

(*a*) Upstream from the Survey Locality F4 are thin-bedded typical Upper Ordovician rocks, which show numerous contortions merely local in their effect. Near the second large meander below the bridge the sudden lithological change takes place. Occasional graptolites may be found within 2 chains of the change at Loc. 27 in the thin-bedded series. cf. *Pleurograptus* sp. and *Diplograptus* prove their Upper Ordovician age.

The succeeding thick-bedded green nodular shales and sandstones have, on the limited search given to them, yielded no fossils apart from the usual "worm tracks."

The lithological break takes place suddenly, and the section does not show a transition as seems to be the case north of Wildwood. The gentle minor folding of the Silurian is in direct contrast to the crumpling of the Upper Ordovician, but near the contact dips and strikes are similar.

(*b*) Along Konagaderrer Creek sparingly fossiliferous Upper Ordovician beds outcrop, exhibiting all the characteristics of such beds further to the south. These extend to the flat near the mouth of the creek. Near the junction of the creeks typical Silurian beds occur, the typical greenish brown nodular mudstone and brown sandstone of the Silurian. These beds are separated by a gap of about 4 chains from the typical Upper Ordovician beds. Although the Silurian beds nearest to the Upper Ordovician dip to the east, the creek sections, both north and south of this, point to the fact that the dip observed is on one of the minor folds. No trace of the Conglomerate indicated on the Quarter Sheet was found. The Konagaderrer area, like the Wildwood section, would repay intensive field work.

XI. General Remarks on Ordovician–Silurian Boundary, West of Melbourne.

The actual line of contact cannot be definitely placed at any of these localities, but can be fixed within a chain or two. The lithological change takes place suddenly, although when examined in detail, as at Wildwood, there is a progressive change which becomes apparent within the limits specified. Apart from this lithological change, there is no evidence of an unconformity. Moreover, the dips and strikes in any one of the sections described are the same for both the Upper Ordovician and Silurian as at Jackson's Creek, where it is N.–S., on Emu Creek N. 25°–30° E., north of Wildwood, still further to the east (up to 40° E.) and near Konagaderrer, approximately meridional.

The more crumpled nature of the Upper Ordovician is in direct contrast to the more gently folded nature of the Silurian. Minor folding is present in both systems, but is never as intense in the Silurian as in the Upper Ordovician. This may be due to the lithological difference in the two systems, the essentially thin-bedded, soft mudstone of the one being more plastic than the massively-bedded sandstone and mudstone of the other.

All the sections indicate that there is no noticeable break between the two systems, and that no period of intense folding uplift or denudation preceded the deposition of the Silurian beds. There may be a slight break or disconformity, but the two systems in these sections are to all appearances conformable.

XII. Previous Work on the Relationship of the Ordovician and Silurian in Victoria, and Comparisons with other Areas of the State.

Selwyn(36), in 1866, maintained that the differences in the lithological character, physical structure, and degree of folding between these two rock systems were best explained by their unconformable relationships.

Murray(31) states that the unconformity of Selwyn referred to the lithological character of the rocks "as the precise lines of junction of the two groups have not been as nearly ascertained as to enable it to be stated that they are stratigraphically unconformable."

Since these general statements were made several workers have studied the problem in the Heathcote, Lancefield, Wood's Point, Aberfeldy, South Gippsland, Mount Wellington, Howqua, Tabberaberra, and Wombat Creek areas.

The Heathcote range and the areas along this meridional line have been studied by Lidgey(27). He was unable to find the actual contact of the two rock groups, but states that the conglomerates of the Silurian rocks of the Mount Ida Range contain pebbles of the metamorphic and Lower Ordovician (?) rocks of this area, thus indicating an erosional break in pre-Silurian times. No Upper Ordovician rocks are known to occur in this area. Further to the south it has been shown in the earliest part of this paper that the Upper and Lower Ordovician are conformable.

Gregory(13) is of the same opinion, and shows that the Silurian of the Mount Ida Range contains material derived from the Heathcotian diabases. "These facts clearly show that the Silurian is later than the Heathcotian Series, and is resting unconformably upon it."

Skeats(38) expressed the view that the Heathcotian ridge near Heathcote was a land area in Middle and Upper Ordovician times, and that the Silurian rocks were laid down unconformably on the older rocks. The same author, describing the Lancefield-Romsey area, states that the abundance of conglomerates along the western outcrop of the Silurian rocks, the presence of pebbles in these lithologically similar to the older rocks of the district, the difference of strike of the series, show that the systems are unconformable, and that the westerly portion of the Silurian sea banked against an elevated land area consisting of Ordovician and Heathcotian rocks. Recent work in this area, however, is at variance with these views.

Along this belt it is seen that the actual contact of the Ordovician and Silurian has not been observed, and the only evidence that can be seriously considered is the presence of pebbles of the older rocks in the Silurian conglomerates.

The other worker on the problem in the central part of the State was James(20) who marked the western conglomerate on Jackson's Creek as the base of the Silurian. Silurian beds have been shown to occur beneath this, so that the conclusions drawn from the presence of the conglomerates do not carry any weight.

The other areas where the relationship has been studied are in Gippsland. The Wood's Point and Aberfeldy areas are the most important in this respect. Whitelaw(45), apart from a small area in the south-west of the area mapped, shows that the typical pink and green shales of the Lower Silurian rest on the black slates of the Ordovician. There is thus a lithological break but, apart from the one corner cited, there is no stratigraphical break.

Further to the south, Baragwanath(3) states: "There is no unconformity so far as was observed at the junction of the two formations, and no conglomerate is found at the base of the Mount Useful beds, though quartzites and sandstones predominate at this horizon in contrast to schists and phyllites which make up the bulk of the formation. The distinction between the Upper Ordovician and the Mount Useful beds is essentially lithological dark graptolite-bearing slates in the one case and highly-coloured schists and phyllites on the other."

Keble and Harris(26) publish a sketch plan of the Upper Ordovician and Silurian areas at Mount Easton showing the contact, but do not comment on it.

In South Gippsland, both Upper Ordovician and Silurian rocks have been mapped by Ferguson on the parish plans of Doomburrim, Wonga Wonga, Wonga Wonga South, Waratah, and Tarwin South, published by the Geological Survey. No actual contacts were observed, the boundary being sketched in between known areas of Upper Ordovician and Silurian.

In the next belt to the east work has been done chiefly by Teale(43). On the Howqua area where cherts and graptolites were first found by Howitt, Teale found no outcrop of Silurian rocks. In the Mount Wellington area(44), however, he was able to observe the contact. His remarks, as they compare with conditions in some Bolindian areas, are quoted at length: "The actual contact between the Ordovician black slates and the Silurian can be seen at several outcrops. In all these instances conformity and similarity of dip are shown, but the horizontal extent of the exposures is limited, and when the general boundaries of the contiguous formations are traced, the evidence of an unconformity is more marked. The lithological break is a sharp one in every case, and the graptolites are abundant in the slates to the junction when they stop suddenly." Here again the rocks appear to be structurally conformable and, in the absence of detailed knowledge of the horizons of the beds at their contact, one cannot state whether a disconformity exists.

The most easterly localities where the two rock groups have been studied are at Tabberabbera and Wombat Creek. The former area has been described by Professor Skeats(40), who states that the Silurian rocks consist of limestone, conglomerates, grits, and olive shales, and are of Yeringian age (i.e., Upper Silurian). From a study of the contacts the author states that the relationship is not a normal one, and that faulting is present. Thus no conclusion can be reached as to the relationship of the two rock groups.

Ferguson(12) states that at Wombat Creek the Upper Silurian series rests unconformably on the Upper Ordovician beds, and that the junction can be seen in the field. While on the Wombat Creek the Silurian rests on Upper Ordovician, at the Gibbo Creek the lower beds are of Lower Ordovician age. Much more work is necessary in this area, but there is stronger evidence of an unconformity here than in any other part of the State. The whole area, judging from the physiography, is one affected by considerable crustal movements.

An unconformity of a similar nature appears to occur in New South Wales, where Woolnough(47) shows the Silurian beds resting unconformably on the Upper Ordovician strata.

Keble found at Langwarrin in a Silurian conglomerate interbedded with shales with *Keilorites,* slate pebbles containing *Climacograptus,* suggesting a Bolindian age for the contributing slates. The conglomerate is not basal, and the Silurian-Ordovician contact is masked by Tertiary sands; there is presumably about half a mile between the contact and the conglomerate.

Summarizing the evidence, the only record of an unconformity is that at Wombat Creek; in the other cases it is hypothetical. In the area with which we are dealing, the evidence points to the conformability of the two formations, and excludes the possibility of a general diastrophic period intervening between them. There is evidence, however, of warping movements in eastern Victoria and in New South Wales.

XIII. Ordovician-Silurian Boundary and Associated Anomalies.

Working eastwards from the Bolindian, a lithological change at once becomes evident, and we pass on to typically green, relatively massively-bedded sediments crowded with worm tracks. In soft sandstones, on Jackson's Creek, we find Silurian graptolites, among them being *Monograptus* cf. *concinnus,* and *M.* cf. *fimbriatus,* associated with forms that are common to the upper beds of the Ordovician and lower beds of the Silurian; these are followed by beds that are progressively higher in the Silurian,

all characterized with abundant worm casts. It is apparent, then, that the massive-bedded green worm track beds are low in the Silurian, and we have used them as a bench-mark to separate the Ordovician from the Silurian. We find in sections further north the same green beds marking the same lithological change, and know that in its northward extension, it demarcates the extensive area of Ordovician sediments of Western Victoria from the equally extensive Silurian of Central Victoria.

The early geologists responsible for the Quarter Sheets noted the lithological change and marked the Ordovician-Silurian boundary relative to it. With a conformable junction we would expect in the fossils of the succeeding Silurian, a faunal equivalent to the British Llandovery, as we know it. We have already pointed out that the Llandovery as a series was erected by Murchison in 1867(30), after McCoy had identified the fossils from the areas represented by the several Quarter Sheets, and it is interesting to conjecture where he would have placed them had he seen them. As a matter of fact, fossils from these beds are sparingly represented and poorly preserved; the critical forms are graptolites, few of which were available to McCoy. Partly on McCoy's identifications from the Silurian of Central Victoria, and particularly on those from the Melbourne area, Gregory(13) divided the Silurian into two series, a lower one, the Melbournian, and an upper one, the Yeringian. We propose to show that, stratigraphically, the Melbournian is in a synclinorium in respect to other Silurian beds which must necessarily be older, and as constituted faunally, is the equivalent of the Ludlow Series in the upper part of the Silurian of Britain. The characteristic faunal assemblage of the beds that conformably succeed the Upper Ordovician has not hitherto been recognized in Victoria, and is the equivalent of the Llandovery of Britain.

To establish this, it will be necessary to review the stratigraphical and palaeontological work done on the Silurian, particularly that in and near Melbourne, and examine the premises on which the Melbournian and Yeringian were founded.

XIV. Stratigraphy of the Silurian in and near Melbourne.

Several attempts have been made to show the stratigraphical relations of the Silurian. The earliest was that of Selwyn(34) in 1852. He made a chained and levelled section from 1½ miles W. 15 S. of Kinlochue Inn, Sydney-road, Parish of Mickleham, to Mount Corhanwarabul, near Mount Dandenong, and showed that "the lowest (oldest) bed is exposed in an anticlinal axis west of Diamond Creek, and the highest (youngest) beds occur immediately east of the Yarra and west of the Plenty River."

In 1854(34) he made a shorter section from Hawthorn to Flagstaff Hill, Melbourne, in which he showed the lowest Silurian beds in an anticline which centres approximately in the Richmond flat (Burnley) and the highest beds at Flagstaff Hill.

In 1866(36) he stated that "Melbourne stands on rocks consisting of soft yellowish and brown sandstones and shaly 'mudstones,' with bands of blue or grey shale and hard fine-grained dark-blue rock, having many of the lithological characters of the 'Ludlow Rocks' of Siluria."

In 1902 Gregory(13) commented on the structure of the Silurian rocks of Victoria, particularly those in and around Melbourne. He shows in a section the "Silurian rocks bent into two main anticlinals" (pl. xxv., fig. 5 (not 6)). Along the eastern side of Melbourne is an extremely contorted zone, which is especially well shown in the cutting by the Yarra at the Johnston-street bridge and near Heidelberg. East of this Melbourne fracture zone the beds have a regular dip to the west. This slope is part of a great anticlinal, of which the axis passes through Warrandyte. Along this anticlinal axis is another line of contortions and faults, along which occurs a series of auriferous quartz reefs. The eastern leg of the anticlinal is much steeper than the western; and beyond it we come to the great synclinal which passes through Lilydale and Yering. We will therefore call it the Lilydale synclinal." . . . He states further, "that there is no evidence of the superposition of the Silurian on the Ordovician." . . . "In the neighbourhood of Melbourne the rocks of the Silurian and Ordovician systems are not, so far as I know, exposed in actual contact; for the junction is covered by the basalt sheets. Yet it is possible that the Melbournian rocks rest unconformably on the Upper Ordovician."

In 1910 Jutson(23) made sections (1) north of Kangaroo Ground (AB), (2) from Burts Hill to Warrandyte, and from thence to Templestowe (CDE), and (3) coinciding approximately with the railway from Box Hill to Croydon (FGH). He designated the anticlines and synclines by local names, and his Templestowe anticline is that referred to by Selwyn in 1852 as exposing the lowest beds. His section AB is somewhat north of Selwyn's section, but it shows with Selwyn's section that the lowest beds are on the Templestowe anticline. Section CDE in its eastern extension from Warrandyte approximates to Selwyn's line, but its western extension from Warrandyte is diagonally across the axial strikes. As such it shows the lowest beds on the Warrandyte anticlinorium and the youngest beds in the Bulleen syncline, which is apparently the syncline shown by Selwyn (1852), about 18 furlongs east of his main (Templestowe) anticline. Had Jutson continued his section line west-north-west in the same direction as its eastern extension (i.e.,

approximately at right angles to the axial strike) it would show that the lowest beds are on the Templestowe anticline, and agree with Selwyn's section. Jutson also shows (pl. xcii.) a more detailed section of the minor folds on the Warrandyte anticlinorium, which he states are fractured. In his section (pl. xcii., AB) he shows that the beds continue throughout the minor folding of the anticline, and that faulting has been on an insignificant scale. In other words, it would appear that the beds repeat on the eastern and western limbs of the anticlinorium. Jutson's section (FGH) is somewhat south of the previous section and in relation to it introduces the factor of pitch; the lowest bed in this section is on the Blackburn anticline.

Jutson's work shows that anticlines and synclines in some instances die out, and the lowest beds may be on adjoining folds on sections some distance apart. It also shows what an important factor pitch is in working out the stratigraphical succession.

Junner(22) in 1913 mapped the anticlines and synclines of the Diamond Creek area and, eliminating the effect of faulting and pitch, a section across his map appears to show that the lowest beds are in the Templestowe anticline, thus confirming Selwyn's section.

James(20) in 1920 examined an area between Sydenham and Bulla, and observing a prevalence of easterly dips not in accordance with his ideas of the structure, suggested overfolding to the west, but failed to produce evidence of this. He suggests that the western face of a conglomerate on Jackson's Creek, slightly more than $1\frac{1}{2}$ miles west of the Maribyrnong River, is the boundary between the Ordovician and Silurian.

In 1930 Nicholls(32) made a section from East Burwood to Collingwood, or from a little west of the Blackburn anticline through the Templestowe anticline to a syncline immediately west of what she designates the Studley Park anticline. This syncline is probably the southern extension of one of a series of close folds noted by Selwyn in 1852, in which he places his highest beds. Nicholls shows in her section a break in the vicinity of Studley Park, and also gives a more detailed section (Fig. 1) of the beds from Johnston-street Bridge to Dight's Falls, which shows some degree of faulting in its total effect, probably a reversed fault hading west. Her comments lead one to think that the cumulative displacement of the reversed faults is small, and would not affect the stratigraphical and palaeontological succession to any extent.

If the pitches of the Blackburn anticline between Nicholls' section and Jutson's FGH section could be ascertained the former could be regarded as a western continuation of the latter.

The lowest beds appear to be on the anticline immediately west of the Templestowe anticline. The section to the west of this comprises a number of relatively close folds which cause the same beds to repeat at frequent and regular intervals.

Summarizing all this stratigraphical work, Selwyn's section in 1852 is the only continuous section through the whole of the Silurian beds in the Melbourne district, and it was made when exposures were far less frequent than they are now. Jutson, Junner, and Nicholls have made sections that would have given an accurate presentation of the stratigraphical relations had their efforts been co-ordinated, but up to the present this has not been attempted. The outstanding fact is that all the work done subsequent to Selwyn's pioneer effort substantiates either directly or indirectly his placing of the lowest beds in the Templestowe anticline.

Furthermore, Jutson's and Nicholls' work appears to show that the axis of the Warrandyte anticline and the beds in the vicinity of Melbourne are closely folded, facts which Gregory emphasized and our own observations confirm. We have also observed that the same beds recur at frequent intervals indicating that faulting is comparatively insignificant.

XV. Basis of Palaeontological Subdivisions.

The first attempt to subdivide the Silurian on a palaeontological basis was that of Sir Frederick McCoy from collections of shelly forms and graptolites made by the Geological Survey from 1856 onwards(28). He correlated them with British subdivisions, and in our introductory remarks we have shown the limitations of contemporary knowledge of the Silurian in Britain.

McCoy's subdivision is to be inferred from the Quarter Sheets and also the Prodromus of the Palaeontology of Victoria(28), published at intervals from 1874 to 1882. In 1867 Murchison(30) had already included the May Hill sandstones and the lower Pentamerus sandstones near Llandovery in the Llandovery, but throughout the Prodromus, McCoy used his and Murchison's faunal subdivision of 1852. His reason for adopting the older subdivision was doubtless due to the fact that when the first Quarter Sheets were published, circa 1856, the accepted subdivision was that of 1852. In the Prodromus it was intended to give a detailed description of the fossils collected while the Quarter Sheets were being surveyed. The Prodromus did not appear until some twenty years later, and it would have led to confusion to adopt Murchison's revised subdivisions of 1867, particularly as the 1852 subdivision was inherently accurate, if not complete.

The subdivision used by McCoy is, in descending order—

Ludlow, Wenlock, May Hill Sandstone } "Upper Silurian" (=Silurian).

Bala, Llandeilo } "Lower Silurian" (=U. Ordovician).

Throughout the years covering the collections a development of his ideas is noticeable in that he displays a progressive tendency to place previously examined faunal assemblages higher. The only Silurian graptolite described was *Retiolites australis* (*Stomatograptus*) from Ba56 and 57 (Q.S. 1 N.W.) north-west of Keilor, to which he ascribed a Wenlock age. As we are here concerned with the shelly fauna only in so far as it afforded him the means of determining the age of the beds at certain localities, it will suffice to refer to those beds by their locality names. Taking them as they appeared in the Prodromus, in 1874 he placed two starfish from Moonee Ponds and Kilmore into Upper Silurian and Silurian respectively. In 1876 he referred Broadhurst's Creek, east of Kilmore (Bb18, Q.S. 4 S.W.) to the Wenlock, and Yering probably to the May Hill Sandstone. At this period he relegated the Moonee Ponds beds to May Hill Sandstones. In 1877 he referred to Yering as Wenlock, Mt. Disappointment (Bb17, Q.S. 3 N.E.) as May Hill Sandstone, Bb 22 (Q.S. 4 S.W.) near Kilmore (N.E.) as Wenlock, Bb15 (Q.S. 3 S.E.), Section 44, Parish of Wallan, as May Hill Sandstone, and Section 12, Parish of Yering as "May Hill Sandstones (base of Upper Silurian)." In 1879 he referred flags at Mt. Matlock, beds 4 miles above Starvation Creek and Russell's Creek, Gippsland, simply to the Upper Silurian. Bb15 (Q.S. 3 S.E.) he referred to "May Hill Sandstone of Wenlock Age," and likewise beds at Royal Park and near Kilmore (Bb20, Q.S. 4 S.W.). *Orthoceras bullatum* (Sow.) in cutting at Johnston-street, Collingwood, he relegated to the Ludlow. Bb18 (Q.S. 4 S.W.) at Broadhurst's Creek he still regarded as Wenlock. McMahon's Creek, Upper Yarra and Reefton, Warburton, were placed in the Wenlock.

There is little doubt that McCoy regarded the May Hill Sandstones as either forming an integral part of the Wenlock or the transitional beds ushering in the Wenlock, a faunal distinction that implied no stratigraphical break, and held that the Wenlock, together with the Ludlow, comprised the Silurian. From this stand-point all the collections except one were relegated to the Wenlock or the middle part of what we now refer to as the Silurian. The one outstanding exception is the collection from Johnston-street, Collingwood, which he ascribes to the Upper Ludlow.

In 1902, Gregory(13) stressed the importance of a palaeontological basis for the correlation of his suggested stratigraphical succession, but pointed out the difficulties and insufficiency of

the evidence. Nevertheless, on the identifications of McCoy, Etheridge, and others, he states that "there seems to be evidence of two main subdivisions; the first we may call the Melbourne series or Melbournian; many fossils have been obtained from it at Moonee Ponds and at the Yarra Improvement Works; and it can be traced north-westward from Melbourne through Keilor, East Kilmore, and Heathcote. . . . The second series we may call the Yeringian, after Yering, north of Lilydale, where the beds have yielded a small brachiopod fauna. . . . We should expect this horizon also to appear in the syncline to the west of the Warrandyte anticlinal, but so far I know no definite palaeontological evidence of its occurrence there." He gives lists of fossils from the Melbournian and Yeringian, most of which McCoy ascribes to the Wenlock and May Hill Sandstones. From the point of view of this paper the significant species quoted are *Retiolites australis* (*Stomatograptus*), which McCoy relegated to the Wenlock and *Orthoceras bullatum* (Sow.), which he regarded as Ludlow; Gregory places both species in the Melbournian. In the summary of his conclusions he states that the Melbournian is the lower and the Yeringian the higher.

In 1913 Chapman contributed a paper(4) in which he adopted Gregory's divisional nomenclature in the same order, i.e., he places the Yeringian above the Melbournian. The general facies of the Yeringian he regards as that of the Wenlock Limestone and Lower Ludlow shales (p. 211). Many localities which McCoy referred to May Hill Sandstones or Wenlock, Chapman considers Melbournian, but he agrees with McCoy in placing the *Retiolites australis* (*Stomatograptus*) beds as Wenlock (i.e., Yeringian). He points out that the Yeringian facies predominates throughout the shales and mudstones of the Upper Yarra, and is not narrowed down to the Lilydale synclinal. Commenting on Jutson's placing of the oldest beds in the area examined by him on the Warrandyte anticline, he points out that the fossils from Warrandyte show "a curious mixture of faunal stages (Woolhope Limestone, Valentian, and Wenlockian) similar to that which is met with in the Melbournian of South Yarra, where Wenlock species are commingled with Llandovery" (p. 209). He accepts Jutson's passage beds(24) between the Whittlesea anticline and Merriang syncline; this contribution will be reviewed later. In this paper Chapman erected a new subdivision which he called the Tanjilian, and placed it above the Yeringian. The Tanjilian comprises the Panenka shales of Mt. Matlock, Reefton near Warburton, and the Panenka beds of the Jordan River series, which "lie on the Walhalla Syncline and abut on Upper Ordovician graptolite beds." He does not regard these as older than Upper Ludlow. He appends a valuable list of all the Silurian fossils identified from Victoria relegated to the Melbournian, Yeringian, and Tanjilian, or some of them.

The contribution(24) by Jutson, referred to above, was made in 1908 on the Silurian rocks of the Whittlesea area. This area was mapped by the Geological Survey during the period from 1857 to 1868, and shelly fossils were collected from the area (Bb16 and Bb17, Q.S. 3 N.E.); McCoy regarded the fossils from Bb17 as indicating the May Hill Sandstones. Jutson found several other fossiliferous beds which enabled Chapman to give faunal lists. He mapped what he designated the Whittlesea anticline and the Merriang syncline, and suggested the possibility of a fault occurring between them. Summarizing his conclusions, he states that the Silurian rocks can be divided into the Melbournian series (coincident with the Whittlesea anticline) and the Yeringian series (in the Merriang syncline), such series being divided by probable passage beds containing a rich fauna.

Using Jutson's section (pl. iv.) as a basis, several interpretations of it are permissible, depending on whether the fault is normal or reversed, and on the direction and degree of displacement. Considering the facts that we are acquainted with more than one fault on this section line apart from that postulated by Jutson, and that the section is not continuous, the stratigraphical position of the passage beds yet remains to be proved.

Commenting on the fossils from the Yarra Improvement Works (Alexandra-avenue), Chapman(5) says: "The majority of the fossils recorded from the Melbourne division of the Victorian Silurian point to the rocks in which they are found as being low in the series, a view already expressed by Professors McCoy and J. W. Gregory. The recent discovery by Mr. Spry of *Ampyx* supports this idea, for that genus is typically Ordovician, and found only sparingly in the Silurian. The graptolites and the *Streptelasma* also tend to strengthen this conclusion. There is, however, a peculiar and marked admixture of fossils which, elsewhere, are typical of the newer Silurian, as seen in the abundance of starfishes and brittle-stars, which in Great Britain occur in the Ludlow series; as well as in the striking abundance of the genus *Palaeoneilo* of the types almost peculiar to the Upper Silurian or Lower Devonian of North America. On the other hand, when compared with our Yeringian series, the fauna is not so consistently Wenlockian, but more decidedly of an older facies."

In 1913 Junner(22) made an important discovery of graptolites in black pyritic slates from the Diamond Creek mine. T. S. Hall identified these as species of *Climacograptus* and *Diplograptus* which genera range in Victoria from the Lower Ordovician through the Upper Ordovician into the lower part of the Silurian (Llandovery). The bed occurs near the Templestowe anticline, which Selwyn regarded as exposing the lowest beds, and affords a striking commentary on the accuracy of his work.

In 1914, T. S. Hall(14) described *Monograptus aplini* and recorded *M. turriculatus* from Aplin's section, Keilor. He remarked on the former's affinities to *M. exiguus* and *M. nodifer* from zones 22 and 23 of the British succession, which being Tarannon, doubtless urged him to place *M. aplini* as a Melbournian species.

In 1927, O. A. Jones(21) identified and figured several forms from Studley Park, and showed that they could be correlated with Ludlow forms. The Geological Survey has used local names for subdivisions of the Silurian in the Wood's Point and Aberfeldy areas. It is our intention at some future date to correlate these with the graptolite zones of the areas.

XVI. Accumulated Evidence in Conflict with Gregory's Succession.

The following discussion will be more intelligible if we consider the divisions in terms of the local nomenclature on the basis that McCoy was in agreement with Chapman that the association of shelly fossils from Yering, i.e., the Yeringian, "has the general facies of the Wenlock Limestone," and is not older. The Melbournian then, according to Gregory and Chapman, should represent a lower horizon, and be either low Wenlock or Llandovery. The validity of the Tanjilian has been questioned by Skeats(39), and we restrict ourselves to a discussion of the position of the Melbournian in regard to the Yeringian and the place occupied by each of them in the Silurian in the Melbourne area.

We venture to suggest that the statements that the Melbournian is the older member of the series conflicts with—

(*a*) the evidence of the palaeontology and stratigraphy of the Melbourne area—the type locality of the Melbournian;

(*b*) the palaeontology and stratigraphy of the area west of Melbourne;

(*c*) the palaeontology and stratigraphy of the area east of Melbourne.

XVII. Palaeontology and Stratigraphy of the Melbourne Area.

Nicholls' work(32) in the vicinity of Melbourne and our own observations in the Melbourne area lead us to believe that the Melbournian from Studley Park to Moonee Ponds is closely folded, the same beds repeating at frequent intervals. Approximately a thickness of 2,500 feet of beds is exposed between these places.

We record a number of graptolites from this area some of which have not hitherto been examined.

1. Wellington-parade. Collected by A. E. Kitson and F. P. Spry—

Monograptus chimaera (Barr).
M. melbournensis (MS.).
M. cf. tumescens Wood.
M. cf. nilssoni (Barr).

2. Railway Cutting at the bottom of Spring-street. Collected by F. P. Spry—

M. varians var. pumilus Wood.
M. cf. vulgaris var. curtus E. and W.
M. comis Wood.

3. Temperance and General Buildings excavations, corner of Collins and Russell streets. Collected by L. Stach—

M. colonus var. compactus Wood.
M. cf. dubius (Suess).

4. Alexandra-avenue (South Yarra and Yarra Improvement Works. Collected by F. P. Spry—

M. bohemicus (Barr).

5. Studley Park(21)—

M. chimaera (Barr).
M. roemeri (Barr).
M. colonus (Barr).
M. varians Wood.

6. Coburg. Collected by W. Hanks—

M. colonus var. compactus Wood.

7. Merri Creek B4 Geological Survey—

M. chimaera (Barr).

Without exception these forms indicate a Ludlow age, and support McCoy's placing(28) of the shelly forms of the olive mudstones at Johnston-street, Collingwood, as Ludlow. It also supports O. A. Jones(21), who correlated the graptolites from Studley Park with the *M. nilssoni* zone of the Lower Ludlow of Britain. Chapman(4) lists from the Melbournian *Dendrograptus, Monograptus* cf. *concinnus, M.* cf. *cyphus,* and *M.* cf. *dubius,* all from South Yarra. He compared forms to *M. concinnus* and *M. cyphus* in 1910. These forms were collected by F. P. Spry, and are at the National Museum. We have closely examined the Spry collection, and can find no form comparable to *M. concinnus* nor *M. cyphus;* in fact, almost all the identifications given by us from Alexandra-avenue were made on forms from the Spry collection, and an examination of all the graptolites collected by Spry in the Melbourne area discloses the fact that without exception they are of Ludlow age. T. S.

Hall(15) made the comparison to *M. dubius.* We have not been able to examine this specimen, but point out that the identification is consistent with a Ludlow age for the beds from which it was obtained.

The graptolite evidence conclusively points to the Melbournian from the type locality being the equivalent of the Ludlow, and this is supported by McCoy's identification of *Orthoceras bullatum* from Johnston-street, Collingwood, as a Ludlow form. This being so, the Melbournian is not low in the Silurian, and on correlative evidence is higher than the Yeringian assuming that to be Wenlockian.

XVIII. Palaeontology and Stratigraphy of the Area West of Melbourne.

That portion of the area west of Melbourne between Moonee Ponds and Keilor is masked by Tertiary Basalt.

From Keilor, MeCoy(28) records *Retiolites australis* (*Stomatograptus*), and relegates it to the Wenlock. With this Chapman agrees in that he refers it to the Yeringian. Chapman(4) also lists *Cyrtograptus* sp., *Monograptus priodon,* and *M. riccartonensis* from Keilor, and assigns them to the Yeringian. We have examined these forms, and do not agree that *Cyrtograptus* is present. We agree, however, that the beds containing *M. riccartonensis* may be Yeringian, but low in that series. T. S. Hall(14) listed *M. turriculatus,* and described *M. aplini* from Keilor, and regarded it as having close affinities to *M. exiguus* and *M. nodifer,* two forms restricted to zones 22 and 23 of the Llandovery. Accepting Gregory's subdivision of the Silurian, and assuming that the Melbournian would be generally equivalent to the Llandovery, he placed the *M. aplini* beds in the Melbournian. As Gregory based his subdivision on the shelly forms, and the Yeringian is an association of such, the ranges of which have yet to be determined, one cannot say that any given association of shelly fossils is either high or low in that series. Chapman(4) records *Phacops crossleii* as restricted to Keilor and Lilydale, the only record from Keilor other than graptolites. The bed or beds marking the base of the Yeringian have not yet been specified, nor is any section known, with the possible exception of Keilor, where one passes from Yeringian into a series either stratigraphically higher or lower. If some of the Keilor beds are basal Yeringian, the inconsistency, if such exists, between the shelly fossils and graptolites is small, for only British zones 24 and 25 are to be looked for between the *M. aplini* beds and the base of the Yeringian. Strangely enough, Gregory's(13) opinion is that the Keilor beds are Melbournian (i.e., lower than Yeringian), an opinion based mainly on McCoy's identifications, which impelled the latter to assign them to the Wenlock (i.e., Yeringian).

XIX. Palaeontology and Stratigraphy of the Area East of Melbourne.

The general stratigraphy of the area east of Melbourne as adduced from the work done shows that Selwyn's conclusion, that the oldest beds are exposed on what is now known as the Templestowe anticlinal and the youngest beds in what we may call the Melbourne synclinorum, is substantially correct.

The outstanding palaeontological evidence is Junner's discovery(22) of *Climacograptus* and *Diplograptus* near the Templestowe anticline. The generic identifications are sufficient to restrict the beds to the lower Silurian or possibly the Ordovician. Assuming that they are Silurian, they must be correlated with a series below the Wenlock (i.e., Yeringian), since either genus is known not to range as high as the Wenlock. In the British classification(9) they would be placed in the Llandovery.

We have pointed out that the Melbournian, so called, exhibits a Ludlow facies, and since such occurs in the synclinorum to the west of the Templestowe anticline, we must look for the Yeringian on the western limb of that anticline. It would seem from rough measurements made by us that the Yeringian, if it is Wenlockian and is present, is represented by a relatively insignificant thickness of beds.

XX. Revised Subdivision of the Silurian Proposed.

From what has been stated, it is obvious that the basal beds of the Silurian which have been shown to rest conformably on the Bolindian (Upper Ordovician) west of Melbourne cannot be correlated with either the Melbournian or Yeringian of Gregory or Chapman. Furthermore, it has been shown that the Melbournian of Gregory and Chapman, which is regarded by them as representing a lower part of the Silurian, is both stratigraphically and palaeontologically higher, and may be correlated on the graptolite evidence with the Ludlow of Great Britain. McCoy(28), on the evidence of the shelly fauna, placed part of it in the Upper Ludlow.

The Silurian beds resting conformably on the Bolindian (Upper Ordovician) at Jackson's Creek in the Keilor-Bulla area, where they are best shown, can, on their graptolite evidence, be correlated with the Llandoverian (Valentian) of Britain. We, therefore, propose to refer to this series as the Keilorian, and regard it as the lowermost series of the Silurian. The beginning of the Keilorian is marked by the first appearance of the Monograptidae, and comprises all the *Monograptus* beds preceding the incoming of *M. riccartonensis,* which marks the beginning of the overlying series. Chapman,(4) has recorded *M. riccartonensis* from Keilor, but Hall(14) records with certainty from

there *M. aplini,* which he states has close affinities with *M. exiguus* and *M. nodifer,* and *M. turriculatus.* The only other forms examined by us are *Stomatograptus australis, M. marri, M. pandus,* and *M. spiralis* var. *permensis* (MS.). These forms in Britain are representative of Zones 22 and 23 of the Llandovery, and, in equivalence, indicate a higher Keilorian horizon for at least some of the Keilor beds. In the Keilor section we may have both high Keilorian and low Yeringian, but until the ranges of the Victorian Monograptidae are known it is impossible to speak definitely, or what is more important, to fix the limits of the two series. *M. turriculatus,* which is also found in Zones 22 and 23 of the British Llandovery, occurs in association with the conglomerates in Jackson's Creek, and at Keilor, so that the beds of the two places are approximately on the same horizon. A section between the two places shows the existence of a syncline which explains their repetition. Incidentally, we may point out that McCoy regarded the beds at Keilor with *Stomatograptus* as Wenlock, and Chapman relegated them to the Yeringian. Since Chapman regards the Yeringian as equivalent to the Wenlock, at least in part, he and McCoy are in virtual agreement. Furthermore, the occurrence of *M. turriculatus* at both Jackson's Creek and Keilor affords a palaeontological connexion that appears to show the Yeringian or Wenlock is stratigraphically above and succeeds the Keilorian(9); this is also strengthened by the preponderance of *Monograpti* with retroverted thecae at both localities.

Owing to the confusion that must inevitably arise by retaining the serial name Melbournian on the previous assumption that it represents a lower portion of the Silurian, we venture to suggest that the beds of the Melbourne area, the type locality of the Melbournian, be henceforth referred to as the Yarravian. The name is selected on account of the fossiliferous value of the beds along the banks of the Yarra at and near Melbourne. Regarding the limits of the Yarravian, since the graptolite evidence shows that the fossiliferous beds at Melbourne may be correlated with the Ludlow of Great Britain, we would tentatively fix the same limits. It may ultimately be found that the term Melbournian can be retained as a zonal name, but we doubt if even this is desirable.

The sequence proposed here, then, is—

3. Yarravian.
2. Yeringian.
1. Keilorian (oldest).

It should be pointed out that apart from the palaeontological connexion shown to exist between the Keilorian and Yeringian in the Keilor-Bulla area, the stratigraphical section of which is reasonably reliable, there is no undoubted section in which the

Keilorian is stratigraphically connected with the Yeringian or the Yeringian with the Yarravian, a fact which has undoubtedly led to the misconceptions in the past regarding the stratigraphical relations of the Melbournian and Yeringian. The only typical Yarravian locality yielding shelly fossils that may be correlated with a graptolite facies is at Alexandra-avenue. Yering, with its well-developed shelly fauna, has not yet yielded graptolites, although a serious search may disclose them. Fossils other than graptolites from the Keilorian at Jackson's Creek are extremely poorly preserved, and offer little material for correlation.

The great desideratum is a comprehensive section showing the structural as well as the palaeontological relations in which the graptolite fauna, of paramount importance in fixing the finer subdivision of the beds, may be correlated with the shelly fauna. In the absence of this, co-ordinated sections both with and across the strike must suffice. As it stands, the evidence, both stratigraphical and palaeontological, the latter correlated from both the shelly and graptolite faunas, clearly shows that Gregory's subdivision is untenable, and we confidently suggest a substitute based mainly on the graptolite evidence. In this we have the support of McCoy's identifications mostly of shelly faunas on the one hand and Selwyn's stratigraphical work on the other.

XXI. Summary.

The history of the development of our knowledge of the Silurian and Ordovician is reviewed, particularly in so far as it relates to the work of the Geological Survey on the Keilor-Sunbury area.

The work and research of subsequent workers is also reviewed. Sections in the area are discussed in more or less detail, both in regard to the stratigraphy and palaeontology.

Previous subdivisions of the Upper Ordovician in the Australasian Province are commented on.

A revised serial subdivision in Victoria is proposed, in which the Upper Ordovician is subdivided into three series—

3. Bolindian.
2. Eastonian.
1. Gisbornian (oldest).

This revised subdivision is correlated with British occurrences.

Details of the distribution of horizons are given.

The general structure of the Keilor-Sunbury area is discussed.

The Ordovician-Silurian boundary is considered in regard to its associated anomalies.

The boundary of the Upper Ordovician and Silurian is discussed, and several sections showing it are given in more or less detail.

A review of the previous work on the relationship of the Ordovician and Silurian in Victoria and New South Wales is appended.

Work on the stratigraphy of the Silurian in and near Melbourne is critically reviewed, and it is shown that Selwyn's section of 1852 is directly or indirectly substantially confirmed by Jutson, Junner, Nicholls, and others.

The basis of the palaeontological subdivisions is discussed in detail. McCoy's conception of the succession is inferred from his correlations of the faunal assemblages in the light of contemporary knowledge. He regarded the May Hill Sandstones, his lowest Upper Silurian horizon, as either forming an integral part of, or the transitional beds ushering in, the Wenlock. A list of McCoy's correlations is given.

Gregory's subdivision into Melbournian and Yeringian, in which he places the Melbournian as the lower, is discussed, and the palaeontological criteria (based mainly on McCoy's identifications) are examined and compared with McCoy's deductions.

Chapman's view-point in 1913, in which he uses Gregory's subdivisions, is reviewed. His work is based on a number of additional identifications of shelly forms of which he appends a valuable list in his contribution in that year. The horizon of the beds at Whittlesea, which he regarded as indicating passage beds, is criticized on the score of the inadequacy of the stratigraphical evidence.

Junner's important discovery of graptolites at the Diamond Creek Mine, T. S. Hall's identifications from Keilor, and O. A. Jones's correlation of the Studley Park graptolites are commented on.

It is submitted that the observations of others and ourselves indicate that the beds in the Melbourne area are very closely folded. We give a number of identifications of graptolites from various parts of the area (the type locality of the Melbournian) which indicate, exclusively, that the Melbournian may be correlated with the Ludlow of Britain. We review Chapman's graptolite determinations (which we are unable to confirm) and his comments on the shelly forms from the Yarra Improvement Works in the same area, and are unable to corroborate his deductions. To us it is apparent that if the Yeringian "has the general facies of the Wenlock limestone," the so-called Melbournian must necessarily be newer.

The stratigraphy and palaeontology of the area west of Melbourne are considered, more particularly that of the lower part of Jackson's Creek. It is suggested that on the graptolite evidence the beds at Keilor are passage beds and equivalent to the Tarannon and, possibly, the lower part of the Yeringian.

The area east of Melbourne is similarly discussed, and the importance of Junner's discovery of graptolites at Diamond Creek is stressed.

A revised subdivision is proposed in which a new series, the Keilorian, comprises the lowest subdivision of the Victorian Silurian, and directly succeeds the Bolindian. The Yeringian is assumed to succeed the Keilorian. To save confusion it is considered advisable to regard the beds in the Melbourne area under a new name, the Yarravian. The sequence is—

3. Yarravian.
2. Yeringian.
1. Keilorian (oldest).

It is proposed tentatively to regard the incoming of *Monograptus riccartonensis* as marking the beginning of the Yeringian, and to assume, for the present, that the Yarravian is equivalent to the Ludlow of Britain.

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